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The Smoke Problem and its Possibilities.

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IT is a curious and somewhat sad reflection on our boasted civilisation that in these days of luxury and art we take so little care to preserve and purify that upon which, more than upon anything else, depends the healthiness of our lives. It is the towns, and especially the large manufacturing towns, which suffer most from the general want of care in trying to keep their atmosphere purer than it is.

The satisfactory disposal of its sewage, an abundant supply of pure water, and a pure atmosphere, are the three primary factors necessary to maintain the health of any community. Of these pure air is not the least important.

There are many possible impurities in the air of towns, but that which is productive of a vast amount of mischief, and which is at the same time preventible, is caused by the smoke from domestic fires and factories. In many ways the fumes from chemical works are the most harmful of the atmospheric impurities; but they are limited to comparatively small areas, they are under the close supervision of a strong Government Department, and can hardly be considered in the same category as ordinary smoke.

The evils caused by smoke are greater in number and more far-reaching than many people imagine. The fuel chiefly used in this and other civilised countries is some kind of coal; and during the series of chemical processes constituting the combustion of this coal more or less smoke is produced and given off from the chimney. If this smoke is allowed to escape, it becomes gradually diffused in the surrounding atmosphere, from which in time it falls and collects on all objects exposed to its effects.

The actual amount of the smoke sent out into the atmosphere varies a good deal, according to the nature of the manufactures and the number of factories in any particular neighbourhood. From very careful determinations made by Dr. Cohen, of Leeds, it has been found that there are in the immediate neighbourhood of Leeds about 1·2 millegrammes of soot in every 100 cubic feet of the air.

Another similar determination was made by Professor Lewicki, who found, by collecting and measuring the actual quantity of solid matter in a given sample of smoke, that in one cubic metre of the chimney gases there were 0·33 grammes, while the weight of solid soot given off in the combustion of 1 kilogramme of the coal was 6·24 grammes. Putting these figures of Lewicki otherwise, the ratio of the volume of soot to the volume of the gases containing it comes out to be 0·0000147.

From these two measurements some idea may be obtained of the quantity of solid matter contained in the atmosphere and in the actual chimney gases.

The smoke thus dissipated in the atmosphere must in course of time settle, finding a resting place on any objects with which it comes in contact. The sphere of its influence is very large, as the smoke is found to travel for many miles from its source, and to be carried to a height of some hundreds of feet.

The existence of the thick winter fogs in our large cities is greatly due to the presence of smoke in the atmosphere. It

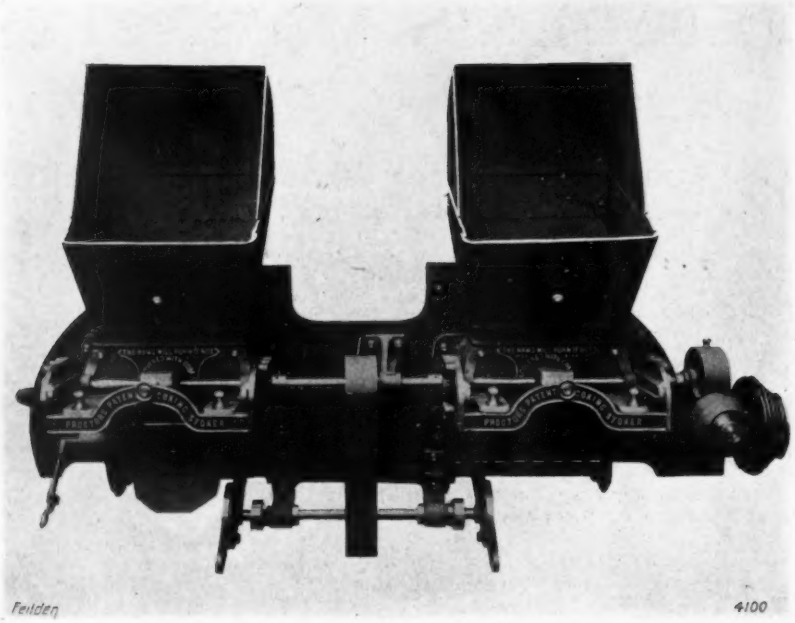

FIG. 1.—PROCTOR'S COKING STOKER.

is held that it is necessary for the formation of a fog that there must be numerous minute particles in the atmosphere, to form nuclei around which the moisture can collect and form fog globules. The presence of a quantity of smoke in the air is just what is wanted to make the formation of fogs more easy, and the sulphurous acids in the smoke help to render the fog more offensive and injurious to the health, especially of those persons whose lungs are not of the strongest.

No further statement is needed to show that the presence of smoke in our atmosphere is not only unpleasant to our senses, but is helping largely to lower the standard of health among the population of our manufacturing towns, and that the abatement of the smoke, if not its complete elimination, is a thing to be desired from all points of view.

The responsibility for its existence can be placed on three separate classes of persons, each of which can do a great deal towards the lessening of the nuisance if it is so minded.

These are, first, the engineers responsible for the making of the furnaces on which the fuel is burned; the manufacturers whose fires produce the smoke; and, lastly, the magistrates who have to try cases of smoke production under the law as it now exists.

As regards the makers of furnaces, it is now generally admitted that these can be made so as to burn the fuel with little or no smoke, and, each year, we have stronger evidence of this. There is no hidden mystery about the production of smoke from a boiler furnace—and it is the boiler furnaces which are by far the largest producers of the black smoke which causes so much trouble and inconvenience. The combustion of the

coal readily divides itself into two stages. In the first, the gaseous constituents of the fuel, consisting of hydrocarbon compounds, are driven off from the fixed carbon, and burn with more or less flame, according to the nature of the particular kind of coal which is being used. The second stage is that of the burning of the fixed carbon or coke, the combustion being unaccompanied by any luminous flame, and not yielding any smoke. The production of smoke occurs during the first stage, and is caused either by the temperature in the later part of the furnace being too low for the complete combustion of the gases to be effected, followed by a deposition of unburnt carbon in the form of smoke; or there may not be sufficient air present to complete the chemical combinations which ought to occur; or both these causes may be at work at the same time. The hydrogen and carbon in the gases require a certain minimum amount of oxygen, the combination, in the case of the former, yielding water in the form of steam, and, in the latter, complete combustion yields carbon dioxide (CO_2), an invisible innocuous gas; and when there is an insufficient supply of oxygen the result is the production of carbon monoxide (CO), a very poisonous gas, which is, in most cases, only given off in extremely small quantities.

That the production or non-production of smoke during the process of combustion is simply a question of air supply and temperature, is shown in the most simple manner by means of an ordinary paraffin lamp in the following way. First apply a light to the lamp with the chimney removed and the wick turned low, so as to only just appear above the wick tube; the oil will now burn with a clear flame and without smoke. Next, gradually raise the wick, so that more oil is burnt and a larger flame produced. When a certain point is

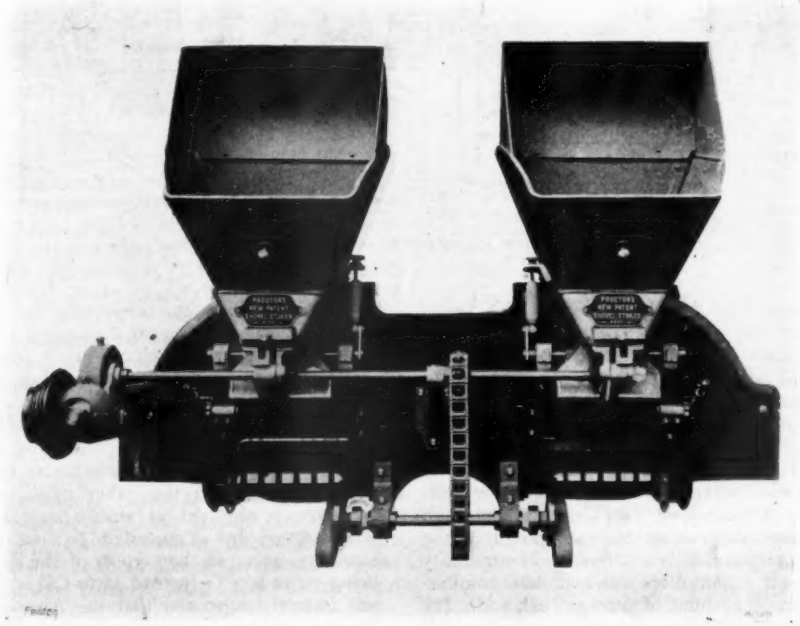

FIG 2.—PROCTOR'S SPRINKLING OR "SHOVEL" STOKER.

reached, it will be noticed that the brightness of the flame begins to disappear and smoke is given off. The reason of this is, that when the flame is small it can derive sufficient oxygen from the still air surrounding the flame and brought to it by the natural current of air produced by convection, to effect complete combustion of the carbon; and the raising of the wick increases the supply of oil, which cannot obtain enough oxygen from the surrounding air for its combustion, and a portion of it is unconsumed and given off as smoke. If, now, a glass chimney is fixed on the lamp, it will be seen that the smoke at once ceases, and the flame again burns brightly, the reason of this being that the chimney concentrates and increases the speed of the upward air current, and oxygen is brought into immediate contact with the flame in sufficient quantity completely to burn the carbon.

Precisely similar phenomena occur in a boiler furnace. A sufficient supply of air must at all times be supplied to the burning fuel, and at the same time a high temperature must be maintained in the furnace and adjacent flues. The quantity of air required for the complete combustion of a pound of average coal, under the most favourable circumstances where all the oxygen is consumed, is a little under twelve pounds. But, as these perfect conditions cannot be attained in boiler furnaces, there must of necessity be considerable excess air, and eighteen to twenty pounds per pound of coal is much more usual, and sometimes greater quantities than this are required.

Looked at from the point of view of the smoke produced, there must at all times be an ample supply of air admitted to the furnace; but all excess air carries away heat which might otherwise reach the water in the boiler, and this carrying away of heat simply means that the boiler is not working as economically as it should. So that in this respect the non-production of smoke and the economical working of the boiler are not always coincident: a great excess of air means lower economy but no smoke, and *vice versâ*. The object to be aimed at is to arrive at a point when there is no smoke produced and the loss of economy is as small as possible under the circumstances. On the other hand, an excessive production of smoke may be accompanied by a considerable loss of economy, owing to the carbon of the fuel being burnt to CO instead of to CO_2. It was formerly supposed that the non-production of smoke must necessarily be

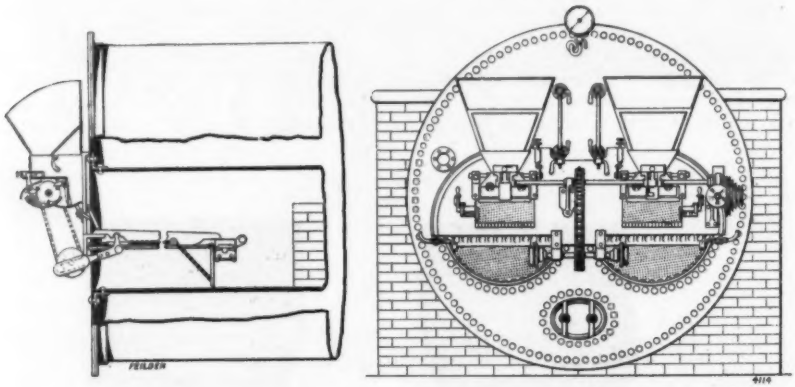

FIG. 3.—ELEVATION AND SECTION OF PROCTOR'S "SHOVEL" STOKER.

accompanied by the formation of CO in large quantities; but this is contrary to known chemical facts, and was conclusively disproved by Mr. Fletcher, H.M. Chief Inspector of Alkali Works, who made many analyses of the gases from a number of boilers, and at the same time took smoke observations of the chimneys.

In hand-fired boilers, not only must the proper total quantity of air be admitted, so as to attain the maximum of economy consistent with smokelessness, but this air must be admitted just when it is required. Coal is thrown on the incandescent fire, and a rapid emission of hydro-carbon gases immediately follows. It is just at this time, immediately after firing, that the maximum air-supply is required, and this should continue until the hydrocarbons are nearly burnt, when it should be gradually diminished until the incandescent stage is reached. Thus the air supply must consist first of a constant quantity to burn the fixed carbon and an intermittent supply following each time of firing.

This excess air is to be admitted above the fire, either through the fire-door or a special valve or door provided for the purpose, and in some cases it is necessary to admit a supplementary supply at the fire-bridge. The admission and regulation of this supplementary air is, in the case of hand-fired boilers, dependent on the fireman who has charge of the furnaces, and its proper regulation may suffer from two causes: either he may have so many furnaces to attend to that he is unable to give to each his full attention, or he may be disinclined to take the necessary trouble to burn his fuel without smoke. With hand-fired boilers, where the conditions are not exceptional and where the boiler has not to be forced beyond its normal capacity, it is possible, by exercising a reasonable amount of care, to burn the fuel without any objectionable quantity of smoke. This has been shown conclusively on many occasions. Influential Committees have from time to time carried out tests, and have promoted stoking competitions. The results have, in all cases been the same in effect, namely, what has been stated above.

Besides the first English Commission of 1881, a second Committee for Testing Smoke-Preventing Appliances, after some years' work, issued a report in 1895. Without going into the details of the work carried out by this committee, it may be stated that the concluding paragraph runs as follows:—

"In the great majority of cases the black smoke thrown into the air during the combustion of coal is preventible, either by hand or mechanical firing, and without great cost to the consumer. Often the prevention of smoke is accompanied with a saving of expense, in that an increase of heat is developed by more perfect combustion of the fuel, and where live fire-bars are adopted, that is, where the bars have an automatic reciprocating motion, an inferior and cheaper quality of coal can be used, and thus a further economy effected."

The final summing up of their opinions, as derived from the tests carried out, is as follows:—

"A manufacturing district may be free from manufacturing smoke—at least from the steam boilers, with which alone the committee have concerned themselves; and as to the means by which it may be so freed the Report contains ample information."

In 1893 a committee in Sheffield—one of the worst smoke-producing towns in the country—summed up a report in the following words:—

"Whilst it is certain that smoke may be almost entirely and completely prevented from steam-boiler chimneys, the conditions of working are so varied that no single arrangement can be expected to meet every individual case; and further, whatever device is applied to a boiler to prevent smoke, its success will in a great measure depend upon the intelligent handling and management which it receives on the part of those to whose care it is entrusted."

A similar report by the Glasgow sub-committee contains the following:—

"The committee are of opinion that, whilst future experiments and inventions may be the means of introducing new and better methods of treatment in the combustion of fuel, enough is known at present to enable steam users to work their boilers with a fair degree of economy, and practically without smoke."

At the conclusion of the Report on the Paris tests carried out from 1894 to 1897, the committee state it as their opinion that the idea that hand-firing can be made smokeless has been disproved by the tests, and that machine-firing is greatly superior. They also state that the tests

go to prove that smokelessness is accompanied by an increase in economy in most cases, and disproves the common idea that when a chimney is rendered smokeless the economy necessarily suffers.

The former of these opinions does not fully coincide with that of the English Committee, but the conditions of hand-firing are not quite the same in France as here; and the opinion of the Committee is given chiefly to emphasise the fact that, as regards smoke, machine-firing is on the whole greatly superior to hand-firing. The consensus of opinion, however, goes to show that in hand-firing, under good conditions, the combustion can be made nearly smokeless.

That machine-firing by means of well-designed mechanical stokers can be made almost perfectly smokeless there can be no doubt, but there are certain existing conditions in regard to their working that must obtain in order that machine-firing may be successful. The kind of mechanical stoker that has been found to be most smokeless in its working is the coking type, where the fuel is fed at the front and carried gradually towards the back of the furnace by a to-and-fro movement of the bars. Here the hydrocarbons are distilled off at the furnace front and pass over the incandescent fuel further back as they are leaving the furnace; and the high temperature, combined with a proper admission of a supplementary air-supply above the fire, renders the combustion smokeless, or nearly so. It is when working in this uniform manner, which is suited to a precise adjustment of the air supply, that mechanical stokers show to the best advantage. Where, however, the demand for steam fluctuates, or where the boiler has at all times to work above its normal capacity, the ordinary type of coking stoker is not applicable. It will not readily respond to a fluctuating demand, and it cannot be easily forced. When these conditions have to be satisfied, a stoker of the sprinkler class, where the fuel is mechanically thrown in such a way as to be uniformly distributed over the whole fire, is the most suitable. In some cases the two types are combined in a single machine, but the effect of the sprinkling device is to produce smoke, especially where the boiler is being forced beyond its normal power. But where a high evaporative power is required, with possibilities of responding to sudden demands for steam and for forcing the boiler when needful, those which combine the advantages of a coking stoker, a sprinkler, and a forced-draught furnace are the most suitable kind for the purpose. The fire-bars have a reciprocating movement, by which the fuel is gradually worked to the back of the furnace; and, as these move separately and are provided with wavy upper surfaces, there is no possibility of any clinker adhering to the bars. A steam-induced forced draught is applied beneath the bars, which are only placed about one-sixteenth of an inch apart. There is also a smaller forced-draught arrangement taking in air just behind the fire-door, at the point where the fuel is just beginning to coke. This accelerates the coking and greatly increases the output of the furnace. The advantages of this arrangement are that the main features of the coking arrangement are preserved, the capacity of the furnace is greatly increased, and at the same time smokeless combustion is attained. Like all other mechanical stokers and forced-draught furnaces, cheaper coal can be used, and a saving effected in this way.

It would obviously be impossible here to describe anything like all the mechanical stokers in use, but five typical and well known machines have been selected for illustration. Of these, two are of the coking kind, and two are of the sprinkling kind, and the fifth combines the advantages of a machine stoker with a forced-draught arrangement.

Proctor's Mechanical Stokers.

Mr. Proctor, of Burnley, makes both a coking and a sprinkling stoker, besides one which is both coking and sprinkling.

On Fig. 1 is shown a view of the front of a boiler furnace fitted with a Proctor coking stoker. In this the coal is first fed into the hoppers as shown; from these it falls upon a plate or ram which is alternately moved inwards—towards the bridge—and outwards again. During the former of these a thick layer of coal is carried well

into the furnace, and, when the ram comes back again it leaves this layer behind it and allows it to fall upon the fire beneath. In most other coking stokers the coal is gradually pushed forward over the dead plate, while here it is deposited on the fire in successive layers.

When the coal has reached the fire in this way it is gradually worked along towards the bridge by the movement of the fire-bars themselves. These are mechanically operated and so arranged that first each alternate bar is brought away from the bridge, next the remaining bars are brought forward, and lastly all go back together, carrying the fuel towards the bridge. By this movement, not only is the fuel slowly worked along from the boiler front, but the spaces between the bars are kept free from clinker. When it leaves the hopper and ram, the coal is cold; as it moves along it first becomes coked, then gradually incandescent, and finally falls over the ends of the bars in the form of ash, all the combustible matter having been burnt.

On Fig. 2 will be seen a view of the outside of the second of the mechanical stokers made by Mr. Proctor. This is the sprinkling type already mentioned, or, as the maker prefers to call it, the "shovel" stoker. Besides this view, a section and elevation of the front of a boiler fitted with this stoker is shown on Fig. 3. In this machine a shovel working radially takes the coal as it falls from the hopper, and throws it on to the fire. The throw of the shovel is made variable, so that the coal is thrown to different distances with successive throws, and thereby the fuel is distributed uniformly over the whole fire. Originally, the Proctor stoker was essentially and entirely a sprinkling stoker; but in the latter designs moving bars have been added, which prevent the accumulation of clinker, and help the backward movement of the burnt and partly-burnt fuel. In order to prevent the front end of these bars from being burnt by the hot fire, the bearer upon which they rest is provided with a number of steam jets, which keep the ends of the

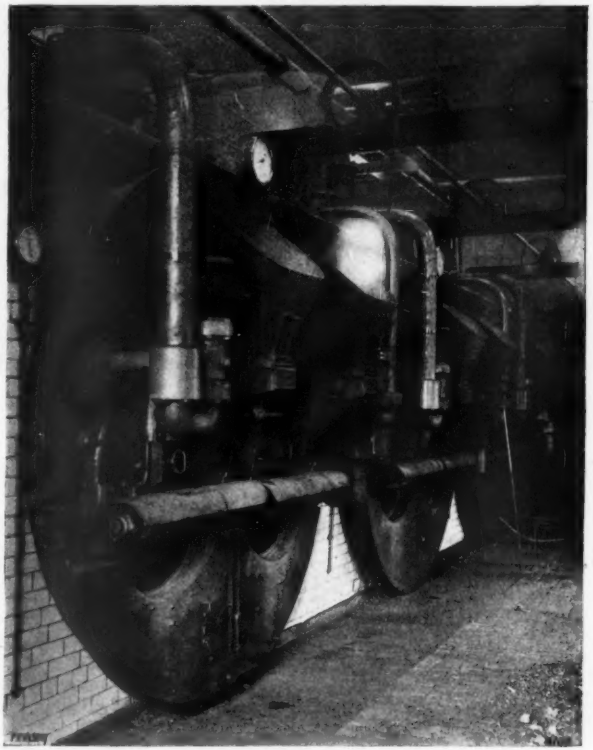

FIG 4.—FRONT VIEW OF A BENNIS SPRINKLING STOKER FITTED TO LANCASHIRE BOILERS.

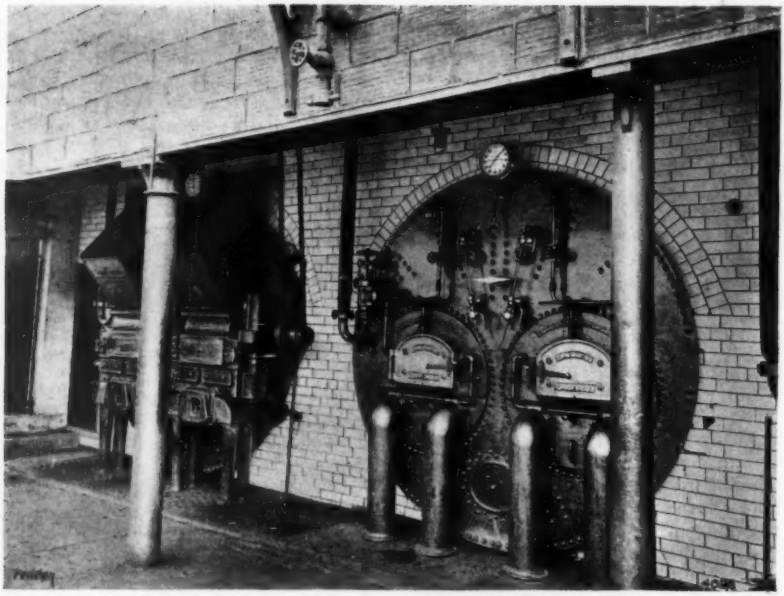

FIG. 5.—VIEW SHOWING OUTSIDE OF MELDRUM'S FORCED-DRAUGHT FURNACE (ON THE RIGHT) AND MELDRUM'S "KOKER" STOKER (ON THE LEFT) FITTED TO LANCASHIRE BOILER.

bars below the necessary temperature. In these stokers all that is necessary is to feed the coal, which has been previously screened to the requisite size, into the hopper, and the periodic release of the spring shovel, helped by the slowly reciprocating movement of the bars, keeps the fire automatically supplied with the right quantity of fuel, and at the same time it is kept clear of clinker.

Bennis' Mechanical Stoker.

This stoker is another of the sprinkling kind and has been used with considerable success. As in almost all other mechanical stokers, the coal must be small and screened, and, at the same time, dry. It is generally shovelled into the hopper, though in some cases it is supplied by a mechanical conveyor. When the fuel falls to the bottom of the hopper it is pushed forward by means of a mechanical pusher or ram. As the coal is pushed forward in this way it falls over the edge of the plate, and, caught by the mechanical shovel as it falls, is thrown on to the top of the fire. The shovel is pulled back mechanically against the tension of a spring and then automatically released, and, springing forward, throws the coal to its proper place on the fire. Each successive throw is of different strength, so that the coal is at one moment sent near to the bridge, the next throw deposits it a little nearer the door, and so on, there being in all four lengths of throw. In this way the coal is distributed on the fire with tolerable uniformity. Messrs. Bennis make the fire-bars hollow and allow jets of steam to blow into them; by which means the bars are kept cool, and there is a current of supplementary air delivered at the back of the fire, where it is useful in helping to complete the combustion of the gases. The bars are also given a slight reciprocating movement, being drawn back one by one and all sent forward together; and

in this way the movement of the burning fuel is helped and the bars kept clean and free from clinker.

A view of a number of Lancashire boilers fitted with the Bennis stokers is shown on Fig. 4. It will be noticed that in these stokers the hoppers are not placed centrally but a little to one side of the centre line of the furnace.

Meldrum's Mechanical Stokers.

Messrs. Meldrum manufacture, in all, three kinds of boiler furnace, namely, their ordinary system of forced draught, the "Koker" stoker, and the more recently introduced sprinkling stoker.

In Messrs. Meldrum's well-known system of forced-draught firing, the ash-pit is closed, and two currents of air forced in under each set of furnace bars. The air is driven in by means of a jet of steam placed in the centre of the air-pipe, inducing a current of air to flow along with the jet of steam. An outside view of the front of a Lancashire boiler fitted with these furnaces is shown on Fig. 5, at the right-hand side of the photograph. The four —two to each furnace —air-pipes will be seen rising from the floor of the boiler-house, and entering the front of the ash-pit. The blowers themselves, containing the steam jets, are in this case placed low down, so that the air is sucked in along a special air trunk, and the noise caused by the steam jets thereby lessened. The air pressure beneath the bars varies from three-quarters of an inch to one inch and a-half of water. In the Meldrum furnace, the bars are only placed about one-sixteenth of an inch apart, so that very small fuel may be usefully employed.

The advantages of this system of firing are that a very cheap kind of fuel can be used, and a saving thereby effected, and also that a much larger fuel consumption per square foot of grate can be obtained, and in this way the capacity of the boiler increased.

The "Koker" stoker made by this firm differs from other coking stokers by reason of the use of forced draught, com-

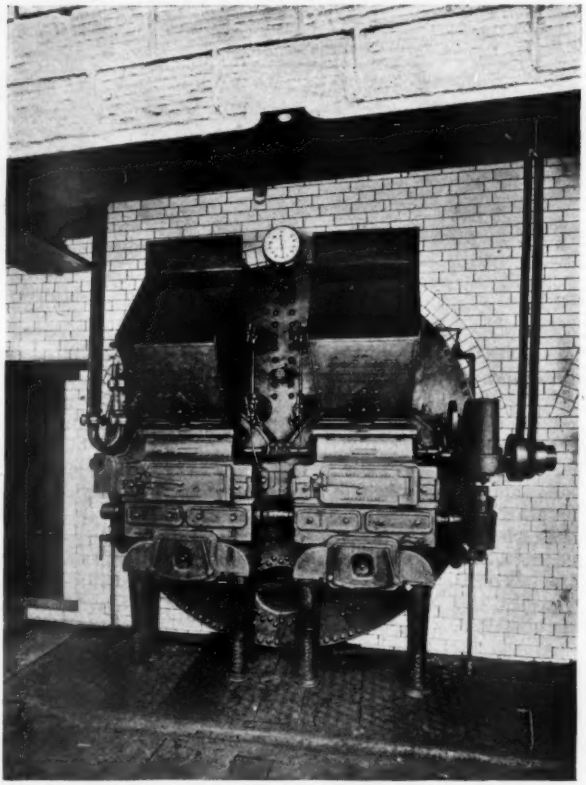

FIG. 6.—FRONT VIEW OF A "KOKER" STOKER FITTED TO A LANCASHIRE BOILER.

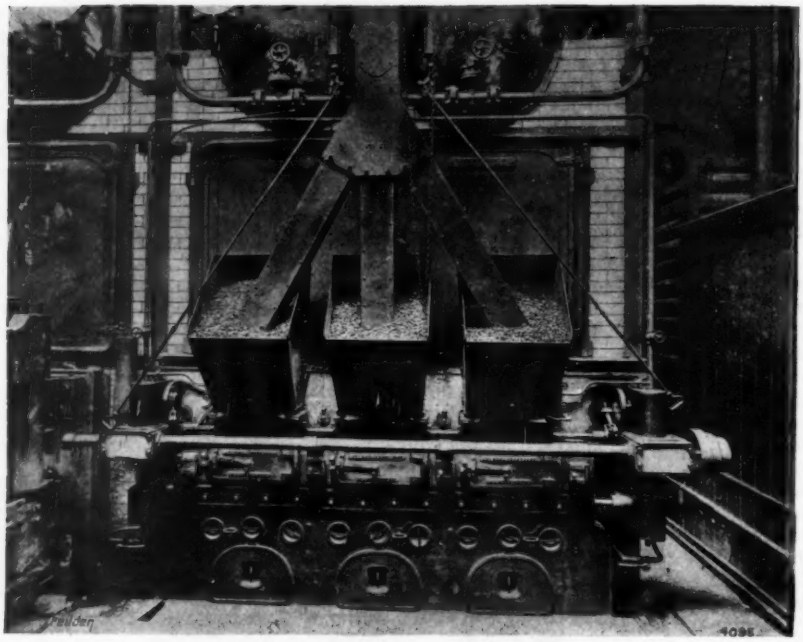

FIG. 7.—FRONT VIEW OF BABCOCK BOILER FITTED WITH THREE "KOKER" STOKERS.

bined with the mechanical feeding arrangement, and the moving bars.

In this appliance the small coal is fed on to the dead plate by means of a mechanically operated pusher, and is gradually worked forward by reciprocating bars, as in other stokers of a similar kind. But the green coal, as it lies in a heap after it leaves the hopper, is supplied with a current of air induced by steam jets, which, playing downwards and forwards, increases the rate of the coking part of the operation.

As the fuel is carried along the bars the combustion is further accelerated by air forced up through the bars, as in the ordinary hand-fired grate made by this firm.

A view of a Lancashire boiler fitted with this stoker is seen on the left hand of Fig. 5, and also upon Fig. 6.

On Fig. 7 is seen another water-tube boiler, fitted with three of these furnaces. It will be seen that the hoppers are supplied with the fuel from a mechanical conveyor, and also that there are in all nine blowers—three for each furnace. These latter are of the ordinary horizontal type, with external air inlets.

A section of the Meldrum sprinkling stoker is shown on Fig. 8, along with a front view of the Lancashire boiler with which it is fitted. In this the fuel is thrown on to the fire by a rotating shovel, and the reciprocating movement is given to the bars as before. Besides this the fire is supplied by air-pressure beneath the bars and over the dead plate.

The coking stoker just described obviously shows a distinct advance on similar stokers which do not make use of forced draught, on account of the greater capacity of the furnace and the cheaper fuel that can be used. The sprinkler has the further

advantage of being capable of dealing with poorer fuel less easy to ignite.

On Figs. 9 and 10 are shown views of chimneys attached to boilers fitted with mechanical stokers.

Referring to the former of these, there are seven boilers to this chimney, six of them always at work. Five are fitted with "Koker" stokers. Previously to these being fitted, this was a most notorious chimney for black smoke; and, being situated at the bottom of the main thoroughfare of a well-known Lancashire manufacturing town, was a nuisance and an eyesore. It may be noted that both the photographs were taken when the works were in full operation, between the hours of 11 and 12 o'clock. Altogether the firm who own the works have sixteen of these coking stokers in use.

In the second photograph, on Fig. 10, two chimneys are shown, these belonging to the same works as the last. The one which is free from smoke is fitted with "Koker" stokers, and is over two very hard-fired boilers, which, previously to the above stokers being fitted, could not be worked without a great deal of smoke, and were the cause of a nuisance to the neighbourhood.

The second chimney, which is constantly emitting black smoke, has all its boilers fitted with some form of mechanical stoker which have not proved at all satisfactory.

The ordinary forced-draught furnace, in which a jet of steam carries an abundant supply of air beneath the fire-bars, is not necessarily smokeless in its working; but may be made so by adding a small steam-jet blast above the fire, or by deflecting some of the air beneath the bars and causing it to flow over the top of the fire or enter the flue at the bridge, or both.

Steam jets carrying in air above the fire and directing a current towards the bridge are found very useful in preventing the emission of smoke from ordinary hand-fired boilers. The great disadvantage of these is that it is very uneconomical to have the jets blowing when the hydrocarbons have been driven off and only the normal supply of air is required. The proper use of these jets is made to depend on the inclination and care of the fireman in charge of the boiler; and it is very often found that they are totally neglected or else allowed to be continually running, at the same time wasting steam and carrying a large excess of air into the flues, which means a lowering of the

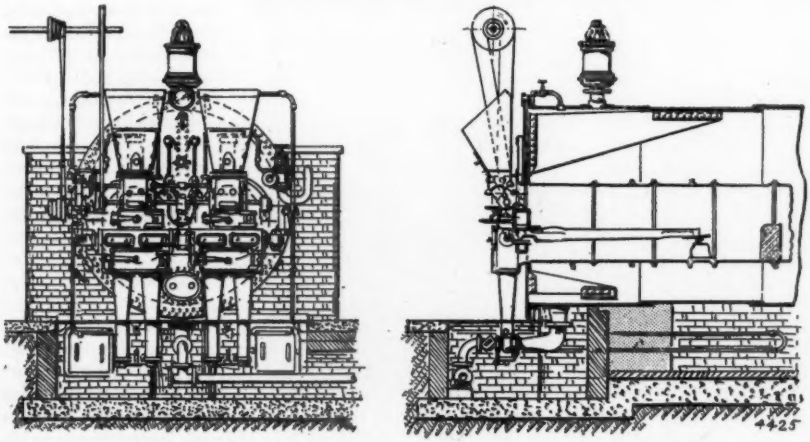

FIG. 8.—FRONT VIEW AND SECTION SHOWING LANCASHIRE BOILER FITTED WITH MELDRUM'S SPRINKLING STOKER.

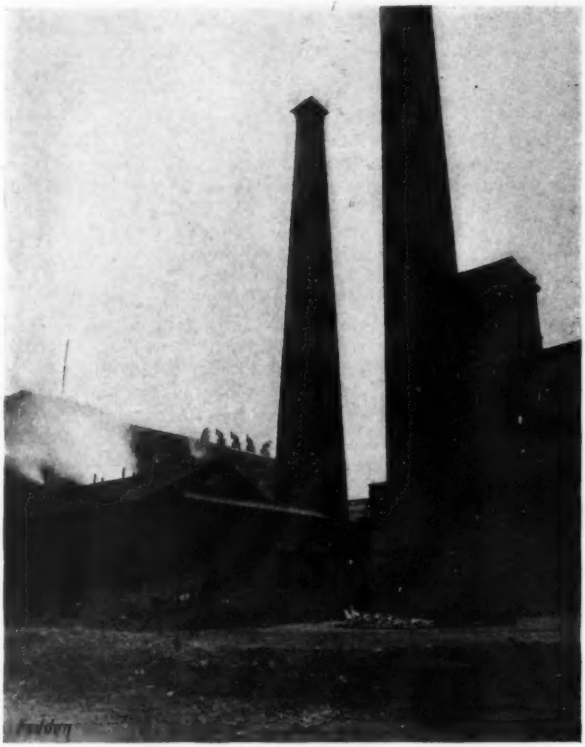

FIG. 9.—VIEW SHOWING SMOKELESS CHIMNEY FITTED WITH A GOOD TYPE OF MECHANICAL STOKER.

efficiency of the boiler. In some cases devices have been made use of for the purpose of automatically regulating this supplementary air-supply; but, so far, no apparatus that the writer knows of has been found to work satisfactorily under all working conditions.

From what has been said it will be admitted that general experience, supported by tests specially made for the purpose, shows that even under the most ordinary conditions of working it is possible to burn coal in a commercial boiler-furnace without the production of an undue amount of smoke, and that by applying carefully selected mechanical stokers the smoke produced can be reduced to a negligible quantity. From which we may take it that it is not the engineer who is to blame. He can make furnaces which will not give off an undue amount of smoke, both for hand-firing and also in the case of mechanical stokers; or, if an existing furnace is disposed to give trouble in this respect, owing to defects in the chimney draught, or because the boiler is expected to produce more steam than it was originally intended for, then the engineer can step in, and, without introducing any such radical alteration as replacing the hand-fired furnace with a mechanical stoker, can, without much trouble, effect a complete remedy at a not very large cost to the owner of the boiler. The remedy in such a case as this will depend on the conditions appertaining to the particular furnace. If the draught is deficient, the application of one of the forced-draught arrangements which are on the market will effect an improvement. In many cases where the draught is fairly good, the application of a steam jet above the fire will secure the desired remedy. But the choice of the method to be applied must be left to the engineer who is called in to investigate the case. Whatever is done, the ultimate success of the plan adopted will depend on the care with which it is carried out. It is of little use introducing a carefully planned modification of the furnace, if the fireman will not take the trouble to obey his instructions, or the owner of the factory does not insist on these instructions being rigidly carried out.

The fireman is often a very difficult person to deal with, and will sometimes prefer to lose his job rather than depart from his accustomed habits; the unfortunate thing is that, when this happens, the new man may be just as bad.

When a furnace is giving trouble in regard to smoke, the first thing to be done is to have it very carefully fired by a man who thoroughly understands his business, care being taken with regard to the manner in which the coal is put upon the fire, and in the regulation of the air supply. Every chance should be given to the furnace to do its best under the existing circumstances; and, if there is still smoke produced, some more drastic measures must be applied. The trial of hand-firing will probably have indicated in what directions improvements are required; and will show the engineer in charge whether the draught is deficient, or whether more air is required above the fire, and so on. Very likely one or two small and not costly modifications will be found to effect the desired result, or it may be necessary to go further and introduce a forced-draught furnace or a mechanical stoker. But the chief point to bear in mind is that it is a great mistake to plunge, without thoroughly considering the whole matter, into a large expense which may after all turn out to be so much money wasted. A millowner must remember that every maker of boiler furnaces, whether hand or machine fired, says that his is the best, and is smokeless. Often this latter is true, but more often it may not be true when applied to the particular case in question.

The legal aspect of the smoke question is in a most unsatisfactory state. At the present time, Section 91 of the Public Health Act of 1875 provides for the prosecution and fining of persons who negligently cause black smoke to issue from the chimneys of their works or factories in such quantities as to be a nuisance to the neighbourhood in which it occurs. Information, as to such a nuisance, may be given by any person who considers himself or herself aggrieved by

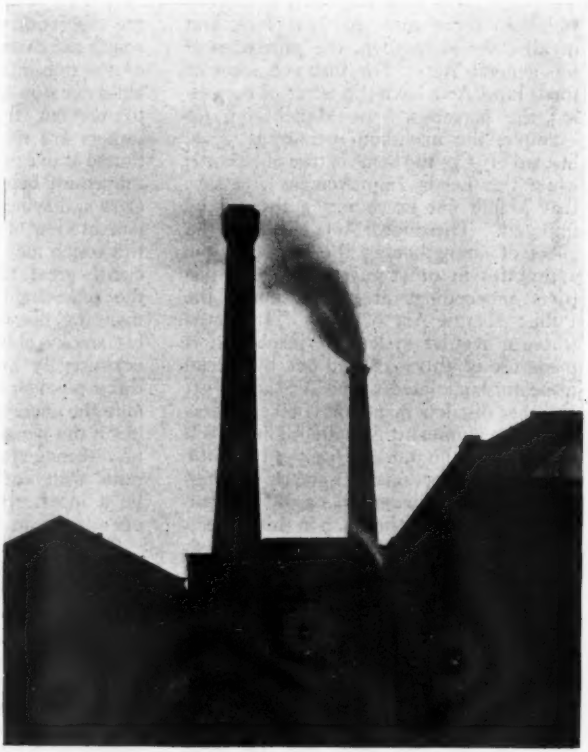

FIG. 10.—VIEW SHOWING TWO CHIMNEYS, ONE BEING FITTED WITH AN UNSATISFACTORY TYPE OF MACHINE STOKER, AND THE ONE WITHOUT SMOKE WITH MACHINE STOKERS THAT HAVE PROVED SATISFACTORY IN THEIR WORKING.

the nuisance. This information is to be given to the local authority, who will take the necessary action. Or a private individual may take action without the help of the local authority. It is also possible for a local authority to take proceedings under this Act against an offending person whose factory chimney is outside its own district, provided the effects of the smoke cause a nuisance in its district. If the local authority is not thought to be doing its duty in the matter, the Local Government Board can step in and interfere. The penalties imposed are limited to £5 for a single offence.

In addition to this Act, many of the local authorities have their own local Acts, which in some cases partly replace, and in all cases strengthen, the provisions of the general Act. For instance, some of these local Acts have the effect of increasing the penalties. In Manchester, for example, the maximum penalty is £10, instead of £5; the same is true of Salford; while the Leeds Improvement Act says that a fine not exceeding £20 may be imposed. These local Acts also have the effect of strengthening the hands of the authorities in other ways. In some districts proceedings are taken under the Public Health Act of 1875. In towns where a regular system of inspection is made use of this is carried out by special inspectors appointed by the local authority. In other districts no action is taken unless a definite complaint is made. Thus it will be seen that the powers employed and the systems of inspection differ greatly in different parts of the country, hardly any two towns being quite the same in this respect. Besides these differences, the actual definition of what amount of smoke constitutes a nuisance is very variable. In one town a millowner may be allowed to produce black smoke for six minutes in every hour, while in others the time may be only half as much. And, moreover, the manner in which this quantity is estimated is not based on one general system, as it should be. In one case there will be three grades of smoke—"black smoke," "ordinary smoke," and "no smoke;" while in others there will be five grades. The best system is one in which there are four or five grades, each one having a fixed numerical value, so that all the smoke, of whatever density, can be reduced to its equivalent of black smoke. Thus in the English Committee (1895) there were four shades of smoke—"dense," "medium," "faint," and "no smoke;" and these had the respective values of 3, 2, 1, and 0. The time during which each of these four was emitted was carefully noted, and an average obtained by making use of the above values, which gave the equivalent black smoke emitted in one hour.

The mode of dealing with the smoke nuisance is defective in three distinct respects. To begin with, the law is defective, inasmuch as it leaves too much to the discretion of the police courts before which the cases are tried, both as to extent of the nuisance committed and as to the ability or non-ability of the offending party to prevent this nuisance. Many millowners are ready with the excuses mentioned above; and the magistrates forming the court, being often men of their own class and sympathies, are apt to take a too lenient view of the case. Then the penalties which may be imposed are not sufficiently great to impress on the owner of the offending furnace the necessity of mending his ways. If the cost of curing his smoky chimney is £100, and he is occasionally fined small sums of two or three pounds, he will not be inclined to take the necessary steps to effect a remedy; but if the penalty were made small for the first offence and increased in a geometric ratio with each repetition, there would be a much stronger inducement for the offender to do his best.

Then the amount of smoke which is to be allowed in the hour should be clearly defined and made uniform for the whole country, and one method of estimating this should be adopted.

The most pressing need of all is, in the opinion of the writer, for the establishment of a small branch of the Home Department, which would have the complete control of all the smoke-producing chimneys in the country. This sub-department might be similar in its constitution and manner of working to the Department of Factory Inspection, or that of the

Inspection of Alkali Works. It could appoint a number of thoroughly trained engineers as inspectors, each having control of a district, with a number of sub-inspectors to carry out the actual observation of the chimneys. These would report to the District Inspector, who would then be in a position to prosecute, if need be, and at the same time to advise the millowner as to modifications in the arrangement of his furnaces, in this way rendering valuable service to both the millowner himself and to the community at large. Until some such general system as this is adopted the smoke nuisance will never be adequately dealt with.

W. C. Popplewell

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Standardisation of Electrical Machinery.

By OUR ELECTRICAL EXPERT.

ELECTRICAL machinery and appliances now form so large a portion of the world's industries that the standardisation of their manufacture is a matter of the widest international importance. It is, therefore, not surprising that the engineering corporations of the countries most largely interested should, for some time past, have been giving attention to this question.

A committee of the Institution of Electrical Engineers has for more than two years been engaged in drawing up a report, but it has not yet seen the light. Valuable reports, however, which are well worth the attention of all manufacturers of electrical machinery, and of all consulting engineers concerned with its specification, have been issued by the American Institution of Electrical Engineers, the American Society of Mechanical Engineers, and the German Association of Electrical Engineers.

It would be an insult to the intelligence of the readers of this Magazine to indite a formal argument in favour of standardisation. Standardisation is nothing more or less than organisation of manufacture, and the question of the course to be followed in order to obtain the best results is hardly more open to argument than the desirability of the final result.

In the earliest stages of any industry the work must be tentative or experimental. When a product is developed which is worth placing upon the market, some form of organisation or standardisation of its manufacture becomes imperative in the joint interests of the maker and the buyer.

In a well-managed factory, standardisation will progress on very much the same lines as natural selection in the organic world, the final result, the survival of the fittest, in view of the environment, being the same in each case. As the number of manufacturers engaged in the industry increases, the competition between them will take the place of the struggle for existence in the organic world. In the former case, however, the process of development will be accelerated, and the elimination of the unsuitable will be effected with the minimum amount of loss, in proportion to the collective amount of intelligently directed experience brought into play.

It is clear that this calls for intelligent co-operation amongst those who direct and influence the industry. In the engineering industries these will be manufacturers and consulting engineers.

Electrical standardisation is following very closely upon these lines. The great engineering societies are effecting the co-operation of their members, embracing both manufacturers and consultants, in order to combine the results of their experience. The next and final step will be to make the co-operation international by bringing into one combination the results arrived at by the experience of the several nations engaged in advancing the electrical engineering industry.

Owing to the rapid intercommunication of knowledge of this subject, mainly through the agency of the technical press and the publications of the engineering societies, this has already been effected to a very considerable extent; but complete and formal international co-operation is most desirable, and it is with the greatest pleasure we note the emphatic manner in which this is insisted upon in the recent inaugural address of Mr. C. F. Scott, the newly-elected President of the American Institute of Electrical Engineers.

The committee of the American Society of Mechanical Engineers confines itself in its report to the standardisation of engine and dynamo manufacture, and deals with the following points:—The standard sizes of units recommended from 25 up to 200-kilowatt capacity; the corresponding

revolutions per minute, with a permissible variation of 5 per cent.; the sizes of shafts for the two classes of centre-crank and side-crank engines, the diameters being determined by the permissible deflection; the length along the shaft required for the generator, two classes, long and short, being provided for, to allow for the marked differences in practice existing among the leading American engine-builders; the height of the axis of the shaft over the top of the sub-base—to reduce to a minimum the stock of sub-base patterns, a standard pattern, with a standard adjustable end for each unit, is suggested, the two classes of vertically and horizontally split generators being provided for by rectangular seatings and stools respectively, which can be attached before sending the pattern to the foundry. Armature fit is next considered, the armature bore being of the exact size given in the table accompanying the report, and the allowance for fit of $\frac{1}{1000}$ in. for shafts of 4 ins. to 6 ins., and $\frac{2}{1000}$ in. for those of $6\frac{1}{2}$ ins. to 11 ins., being provided by increased diameter of the engine shaft. To fix responsibility for fit, it is suggested that the dynamo builder should furnish a gauge the exact diameter of the bore, and that the engine builder should make the necessary allowance for the press fit. For standard practice it is proposed that the overload rating should not exceed 25 per cent. of the rated capacity, and some engine builders ask that the users should be specially cautioned to give special attention to the unit when so operated. Various additional suggestions are made, but are of quite secondary importance in comparison with those referred to above.

The Report of the Committee on Standardisation of the American Institute of Electrical Engineers, which was adopted at the annual convention held at Great Barrington in June last, is a revision, "in view of such suggestions and extensions as experience and practice have since indicated to be desirable," of their report of 1897.

It opens with a number of preliminary definitions, and then proceeds to the consideration, in detail, of the methods to be adopted in specifying and measuring the efficiency of electrical apparatus and equipment, classified under the following sections: Commutating Machines, Synchronous Machines, Synchronous Commutating Machines, Rectifying Machines, Stationary Induction Apparatus, Rotary Induction Apparatus, Transmission Lines.

The permissible limits of temperature rise are next considered, referred to the standard conditions of a room-temperature of 25 degs. C., a barometric pressure of 760 mm., and normal conditions of ventilation—that is, the apparatus under test should neither be exposed to draught nor enclosed, except where expressly specified. The minimum temperature limits fixed are as follows: For the fields and armatures of commutating, rectifying, and synchronous machines, 50 degs. C., to be measured by resistance; for commutator and collector rings and brushes, 55 degs. C., by thermometer; for the electric circuits of rotary induction machines, 50 degs. C., by resistance; for squirrel-cage or short-circuited armatures, 55 degs. C., by thermometer; for the electric circuits of continuous-service transformers and for reactors, induction and magneto-regulators, 50 degs. C., by resistance; for bearings, and for all parts not specified, 40 degs. C., by thermometer. In any case, when the thermometric determination gives a higher value than the resistance measurement, the former is to be taken. In testing railway motors a rise of 75 degs. C. is allowed after one hour's continuous run at 500 volts, on a stand, with the motor covers removed.

Higher temperatures than those specified are allowed in cases where the insulation is of a specially heat-resisting character. It is recommended that high dielectric strength should be specified in preference to high insulation, bearing in mind the fact that the latter can be largely increased by baking, to the detriment of the former. The conditions of testing for dielectric strength for machine insulation, including the testing voltages for the various values of the rated terminal voltages, are very fully specified. The lowest testing voltage is 1,000 volts, for rated terminal voltages not exceeding 400 volts.

From 2,500 to 10,000 rated voltage the testing voltage is double. From this to 20,000 volts rated, an excess of 10,000 volts is to be employed; and after 20,000, the testing voltage is to be 50 per cent. in excess of the normal. Regulation and its determination, and methods of rating receive detailed consideration.

The standard voltages recommended are: For direct-current low-pressure generators, 125, 250 and 550 to 600 volts; for low-pressure circuits, direct or alternating, 110 and 220 volts; for alternating-current primary distributing circuits, an average e.m f. of 2,200 volts; for high-pressure circuits, 6,000, 10,000, 15,000, 20,000, 30,000, and 60,000 volts. The standard frequences suggested are 25, 60, and 120 to 140.

The overload capacities recommended are: for generators, 25 per cent. for two hours; for motors, other than railway motors, and motors for intermittent service, 25 per cent. for two hours, and 50 per cent. for one minute; for synchronous converters, 50 per cent. for half an hour; for transformers, 25 per cent. for two hours.

Recommendations are also made with regard to photometric measurements.

The Report of the Standardisation Committee of the German Association of Electrical Engineers, which was adopted in June, 1901, is drawn up on somewhat the same general lines as the one last considered, but is very much less detailed.

Starting with a room-temperature of 35 degs. C., a rise of temperature of 70 degs. C. with cotton insulation, 80 degs. C. with paper, and 100 degs. C. with mica or asbestos, is allowed for tramway motors after an hour's run in the testing-room; and for all other classes of apparatus a rise of from 50 degs. to 80 degs. C.; and these limits may be exceeded, to an extent not specified, in the case of permanently short-circuited windings.

The overload capacities recommended are: For generators, motors, and converters, 25 per cent. for half an hour; and for motors, converters, and transformers, 40 per cent. for three minutes.

The voltages to be employed in testing the dielectric strength of the insulation are considerably lower, the requirements in this respect being as follows: "Machines and transformers up to 5,000 volts shall be tested for dielectric strength with double their working pressure, but not with a smaller pressure than 100 volts. If the working pressure lies between 5,000 and 10,000 volts, the test pressure must exceed it by 5,000 volts. If the working pressure is above 10,000 volts, the test pressure should exceed it by 50 per cent."

A brief comparison of the standards adopted for temperature rise, overload capacity, and the testing of dielectric strength, in America and Germany respectively, with each other and with British practice, will serve well to illustrate the importance of arriving at a uniform international system of standardisation.

When allowance is made for the German room-temperature being taken as 35 degs. C., and the American as 25 degs. C., the rise specified for the lowest class of insulation is about 5 per cent. less under German rules than under American. The rise of 10 degs. C. when paper insulation is employed in place of cotton is an interesting point. The best Manilla paper has considerably higher heat resistance than cotton, but this is by no means the case with inferior qualities of paper. For example, if jute paper were employed, it would deteriorate at a decidedly lower temperature than cotton.

It should also be noted that such high limits as these do not by any means represent the best British or American practice, which would certainly not exceed an allowance of 40 degs. C., taking 25 degs. C. as the room-temperature. A rise of as much as 50 degs. C. is sometimes allowed in British specifications when the service is more or less intermittent and there is no liability to more than occasional momentary overloading. With regard to overload capacity, the American allowances are small in comparison with what is expected here, which is more like a 50 per cent. overload for a considerable time and a momentary overload of 100 per cent. In the case of central station generators, many of our engineers demand a 100 per cent. overload capacity for very considerable periods. The

demand made by some of the American engine builders that the units should receive special attention when running at 25 per cent. overload is extremely significant, as indicating the very narrow margin allowed in the rating of many American machines.

In Germany, the margin in this respect is still lower, as the 25 per cent. overload is specified not to exceed half an hour. In testing dielectric strength, the American values of the testing voltages may be considered good practice. Here a minimum of 2,000 volts is considered advisable in place of 1,000; it cannot, however, be considered necessary for testing the quality of low-voltage insulation; the effect of the higher voltage would in practice merely make a little more certain the detection of mechanical damage to the insulation occurring in the winding, and it is a question quite open to argument whether the small additional security thus obtained is sufficient to compensate for the additional expenditure. With regard to the high voltages, we have at present no experience in this country.

It will be noted that the excess voltages prescribed by the German regulations are very much lower all through, and would certainly give considerably less security against inferior insulation than the American, even in the case of the higher voltages. The German rule allowing low-voltage insulation to be tested at pressures beginning with 100 volts, would not here be considered a test of dielectric strength at all, but merely a means of detecting exceptionally bad places in the winding.

The general effect of these points would be that, in comparison with a British machine by a maker of repute, an American machine of the same rated power, running at the same speed, and taking full advantage of the American rules, would have a much smaller output, and would be the equivalent of a smaller size under the British rating. The difference in the case of a German machine would be still greater, with a greatly increased liability to inferior insulation.

The rating differences are not of very great importance to purchasers who are themselves competent engineers, or who have competent advice; but they give undue advantages to the American manufacturer, and still more to the German, in the very numerous cases where the purchaser merely compares the list prices of machines running at the same speed, and would probably look upon a guarantee of compliance with the rules either of the American or the German Society as promising a better machine than one of similar rating offered to him by the British maker.

In conclusion, we may refer to the good work which is being done in promoting standardisation, both by the Cable Makers' Association and the Electric Plant Manufacturers' Association. Various firms are also individually doing good work in the same direction, a noteworthy example of which is given in the catalogue of dynamo and transformer stampings recently issued by Messrs. Sankey & Sons, of Bilston, in which they give drawings to scale, a few being half-size, but mostly full-size, of all the more important stamping tools in their possession. This makes it easy for the designer in most cases to get out stampings which can be made without the need of special tools, and therefore in many cases will effect a saving. It must have been a costly undertaking, but the expenditure will probably prove an extremely remunerative investment to the firm.

The Aberdeen Cable Subway and Outfall Sewer.

By G. R. G. CONWAY.

THE Town Council of the City of Aberdeen, during the Parliamentary Session of 1898-9, obtained powers for reconstructing the entire drainage system of the city. The new works, known as the Girdleness Outfall Scheme, were designed by Mr. Wm. Dyack, M. Inst. C. E., the burgh surveyor, and were favourably reported upon in 1898 by Mr. James Mansergh, F.R.S., past President of the Institution of Civil Engineers. The scheme involves the construction of large intercepting sewers and storm-water culverts, and it is expected that nearly £200,000 will be spent in their execution.

One of the most important sections of this scheme is the construction of a main outfall sewer, a little over three miles in length, at a cost of £75,000. This sewer intercepts the whole of the drainage of the western district of the city. Commencing at Skene Street, the sewer passes by way of Golden Square, South Silver Street, Crown Street, Portland Street, and the North Esplanade, to the south side of Aberdeen Harbour at Point Law. From this point the outfall will be tunnelled under the bed of the River Dee — the tunnel forming an inverted siphon — to the village of Torry, on the Kincardineshire side of the river; the outfall then passes under the high ground of Kirkhill, in a tunnel at one point 90 ft. below the surface, to the north foreshore of Nigg Bay, finally discharging its contents 22 ft. below high-water mark of ordinary spring tides at Girdleness, a rocky point south-east of the city. The outfall varies in size from 3 ft. to 7½ ft. internal diameter.

This work is now in progress. The first part of the scheme, known as section No. 1, has been completed—viz., the outfall sewer from Skene Street to Point Law. The second section, extending from Point Law to Girdleness, is now in hand; but it is expected that fully two years will elapse before the work is completed.

It is not the writer's intention to describe these works, except in so far as they relate to an interesting development undertaken during the construction of Section No. 1 of the outfall sewer.

The works were begun in July, 1900, at Point Law, and were proceeding rapidly

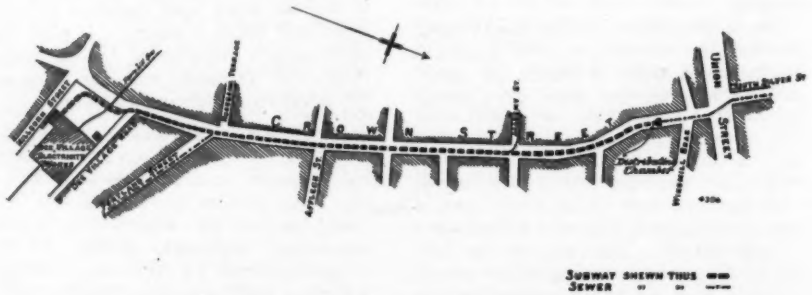


FIG. 1.—PLAN SHOWING ROUTE OF SEWER.

along Portland Street, when an arrangement was entered into between the Sewerage and the Gas and Electric Lighting Committees of the Town Council for modifying the outfall sewer in Crown Street, to admit of the construction of a cable subway on the top of the sewer, from Portland Street to Union Street—a distance of 600 lineal yards.

The electrical department had then recently begun the construction of their new electricity works at Dee Village (Fig. 1), and the city electrical engineer —Mr. J. A. Bell—reported in September, 1900, in favour of some method of making provision at an early date for feeder and pilot cables, which it was necessary to lay from the new works to the different feeding points. He pointed out that probably 90 per cent. of all future cables, either for tramways or lighting purposes, would pass from the new generating station in a northerly direction to Union Street; and that in a few years 40 or 50 cables would have to be laid in Crown Street as the nearest and best route for reaching the centre of the city.

These cables could be laid in three ways:—

(1.) By lifting and relaying the road as may be required and laying the cables on the "solid" system.

(2.) By lifting the roadway and laying ducts capable of receiving the cables and then drawing them in as may be required.

(3.) By constructing a subway.

The first two methods have many objections that may be urged against them; the continual opening up of the street when future extensions are necessary is a source of great annoyance to the public, particularly in a narrow thoroughfare like Crown Street, where a double line of tramway is about to be constructed.

The first method has little to recommend it, and the choice,

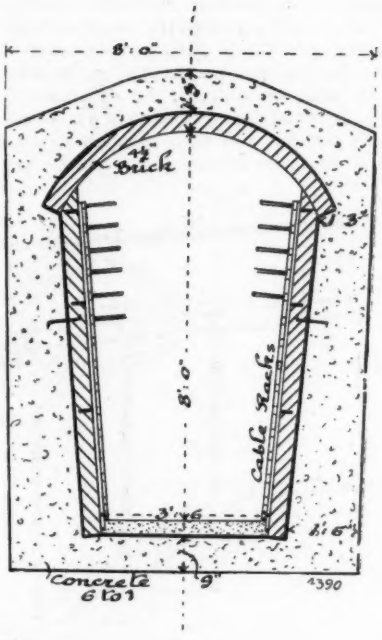


FIG. 2.

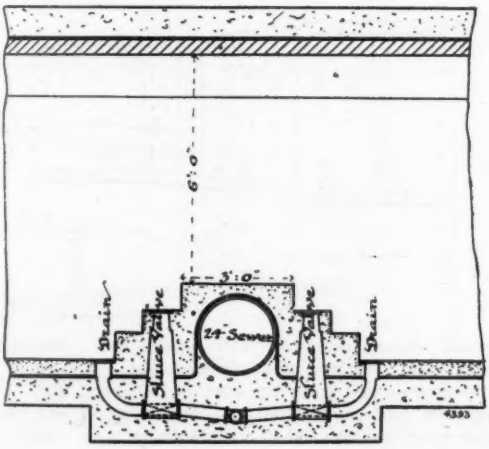


FIG. 3.

therefore, lay between methods 2 and 3. After consultation with the burgh surveyor it was found that if advantage was taken of the opening up of the street when the sewer was being constructed, the difference in cost between the two methods was practically nothing, and there was no question as to the great advantage the subway presented for examination and repairs to cables, etc. It was also certain that a considerable saving in the cost of cables could be made, as a lower grade insulating material might be used in a dry subway.

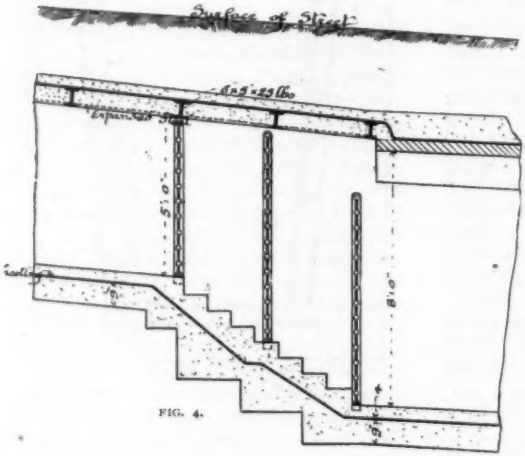


FIG. 4.

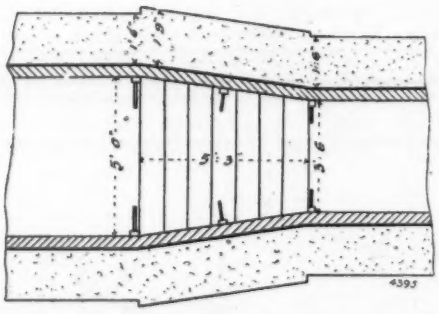


FIG. 5.

The electrical engineer's proposal to construct a subway was agreed to by the Town Council in November, 1900, and the burgh surveyor was authorised to prepare plans, and arrange a supplementary contract with the contractor for the outfall sewer works. The supplementary contract amounted to £8,500, this sum including the construction of the subway from Dee Village Road to Portland Street, apart from the sewer—a distance of 100 lineal yards—and from Portland Street to Union Street, on the top of the new sewer, the design of which had to be considerably modified and strengthened to receive the subway.

The subway is designed to carry all feeder cables with their pilot leads for supplying energy to the tramways, and for the distributing mains in the north, west, and central districts of the city. Provision is made for sixty feeder cables capable of supplying energy equal to from 10,000 to 15,000 h.p.

As the construction of the main sewer was proceeding up Portland Street, a start was made in December, 1900, a few yards within the land belonging to the new electricity works at Dee Village. The general type of subway adopted is shown in Fig. 2; it is of 5 to 1 concrete, lined with red brickwork, with an arched roof. The height is 8 ft., the width at the bottom 3½ ft., the walls having a batter of 1 in 12, thus giving a width of 4 ft. 8 ins. at the springing of the arch. Between the inner lining of red brickwork and the concrete walls is placed a layer of Callender's bituminous damp-proof sheeting with the object of keeping the subway absolutely dry. As an additional precaution, throughout those parts of the subway where wet, clayey and sandy soil was passed through, a double thickness was placed over the floor and carried up 12 ins. on either

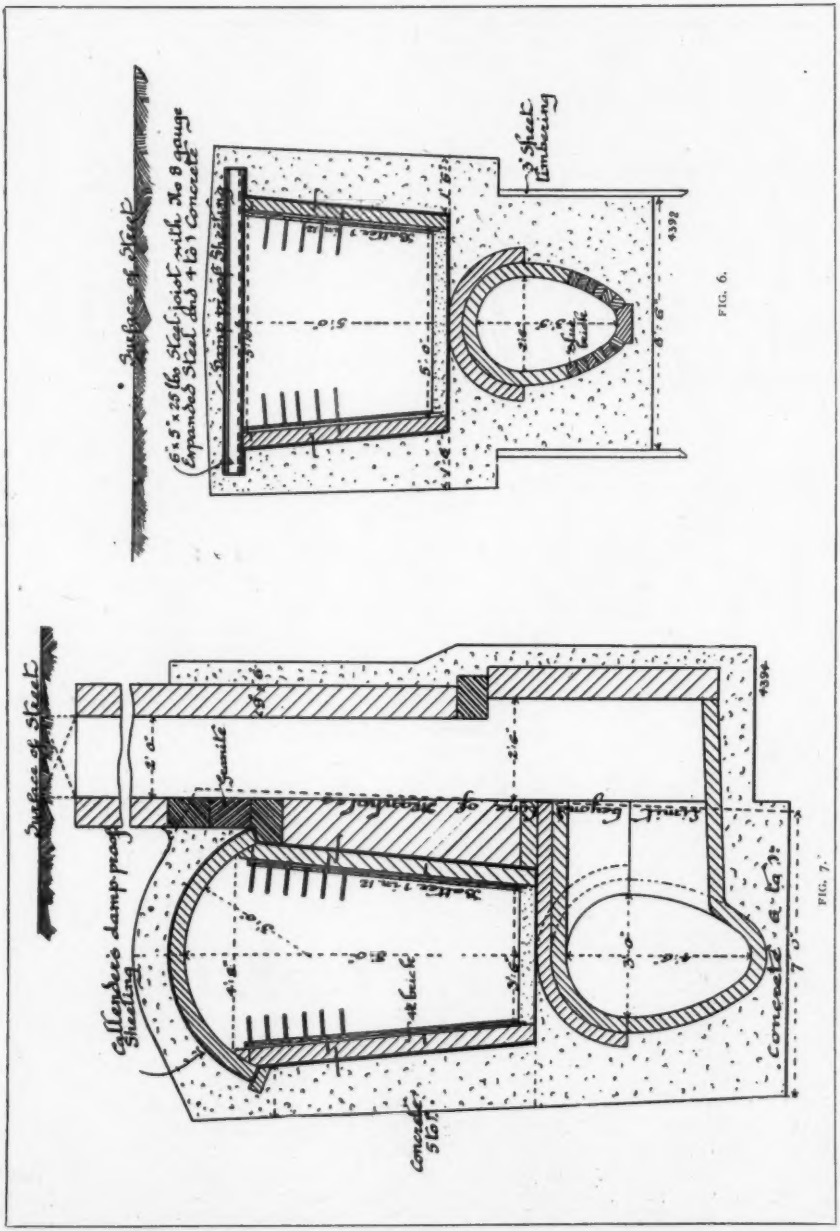

Surface of Street
6"x5"x25 lbs Steel joint with No 8 gauge Expanded Steel and 12" Concrete
Boards to roof Sheeting
3" Sheet Lumbering
Sluice
Surface of Street
Gallopher's damp proof Sheeting
Concrete 6 to 1
Concrete Sleeper

FIG. 6.

FIG. 7.

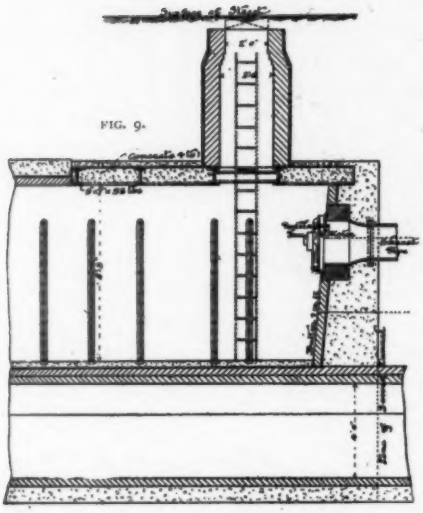


FIG. 9.

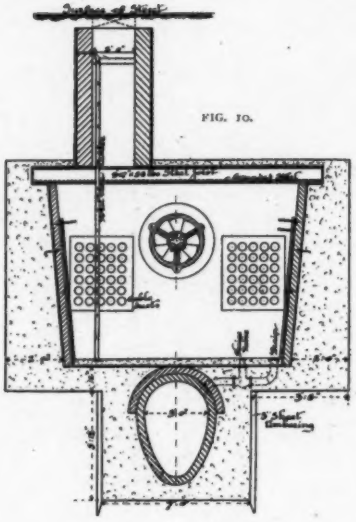


FIG. 10.

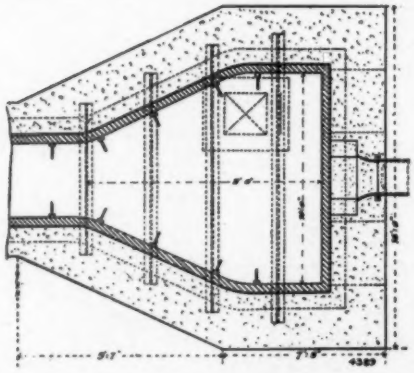


FIG. 8.

side. The floor is made of 6 to 1 cement concrete, 3 ins. thick, finished off with a layer of fine stuff 1 in. in thickness brought to a smooth surface.

From Dee Village Road to Portland Street the subway was constructed as shown in Fig. 2, a 9-in. fireclay pipe encased in concrete being laid at the east side to take the local house drainage, and at the west side an existing stone culvert, $3\frac{1}{2}$ ft. high by 2 ft. wide, was repaired and plastered inside, and is now used to convey storm waters during heavy rains from the new sewer at the top of Portland Street to the Ferryhill Burn. Into the brick walls of the subway cast-iron cable racks were built 6 ft. apart, each rack containing 14 holes tapped with a thread to receive $\frac{3}{4}$-in. wrought iron pins, to carry the porcelain insulators supporting the cables. These pins are 8 ins. long, and are each intended to receive two rows of cables.

At Dee Village Road, owing to the limited depth between the existing 24-in. pipe sewer and the roadway, it was found necessary to arrange the sewer as shown in Fig. 3, the original fireclay pipes being replaced by others of cast-iron, encased in cement concrete. Steps were formed over the sewer in the subway, and at each side was placed a 3-in. sluice-valve with an outlet into the Ferryhill Burn, to be used in the event of any water gaining entrance to the subway.

At the top of Portland Street the new outfall sewer is joined, and at this point the subway was constructed on the top of

a storm overflow weir, which is designed to discharge the excess waters during heavy floods direct to the Ferryhill Burn. The available space above the sewer was so limited that a modification in the type of subway was adopted. Figs. 4 and 5 show the method adopted in taking the floor of the subway by means of steps to the level of the top of the sewer.

The outfall sewer ascends Crown Street from here with a gradient of 1 in 23; it is 3 ft. 9 ins. high by 2 ft. 6 ins. wide, standard egg-shaped (see Fig. 6), and capable of discharging 63,000,000 gals. a day, with a velocity of 16 ft. per second. With such a high velocity, Staffordshire blue bricks were found advisable for the lower part, with a blue-brick invert-block. The character of the ground passed through changed from clay to sand, with a large quantity of water, and when excavated resembled "slurry." A 6-in. fireclay pipe was placed under the sewer; and, with the aid of a chain drawn through from a temporary sump at the low end, the pipe was kept from silting up, and dealt with the water satisfactorily. The sewer was constructed between 3-in. sheet timbering, owing to the treacherous character of the ground; and the foundation of the subway was formed by levelling up to the top of the sewer with 6 to 1 concrete.

The limited space above the sewer, under the surface of the roadway, extended up the street for a distance of 90 yds., and at the lower end it was only found possible to make the subway 5 ft. high, with a flat roof (see Fig. 6); the width was therefore increased to 5 ft. at the floor level, so that three rows of cables could be placed upon each rack-pin instead of two, as in the lower section; the height is gradually increased and the width decreased, until the depth below the street is sufficient to permit of the ordinary arched type being again adopted. The flat roof is formed with 6-in. by 5-in. rolled steel joists, weighing 25 lbs. per lineal foot, spaced $3\frac{1}{2}$ ft. apart, and filled in with 4 to 1 Portland cement concrete, reinforced with a tension bond of No. 8 gauge expanded steel. The bituminous sheeting was carried over the top of these steel beams, and afterwards additional concrete placed on top, sloped as shown (Fig. 6) for drainage, the total thickness of the two layers being 12 ins. Where the steel joists bear upon the walls, a double thickness of sheeting was used.

As this section was proceeded with considerable difficulties were encountered,

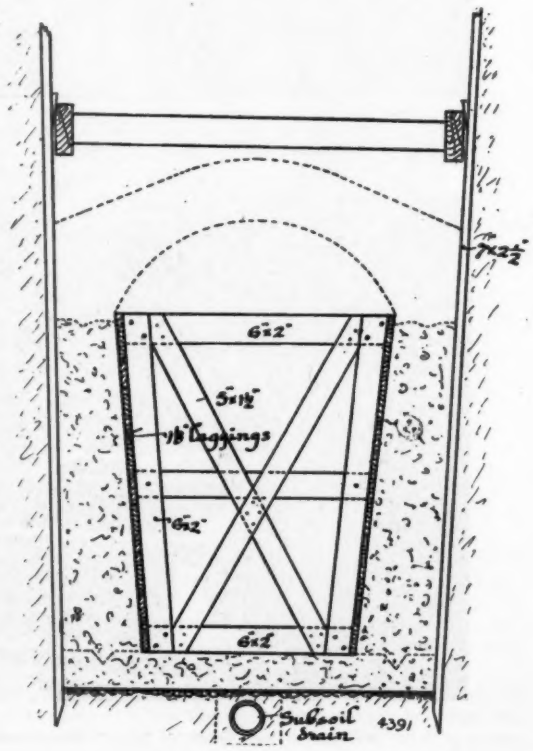
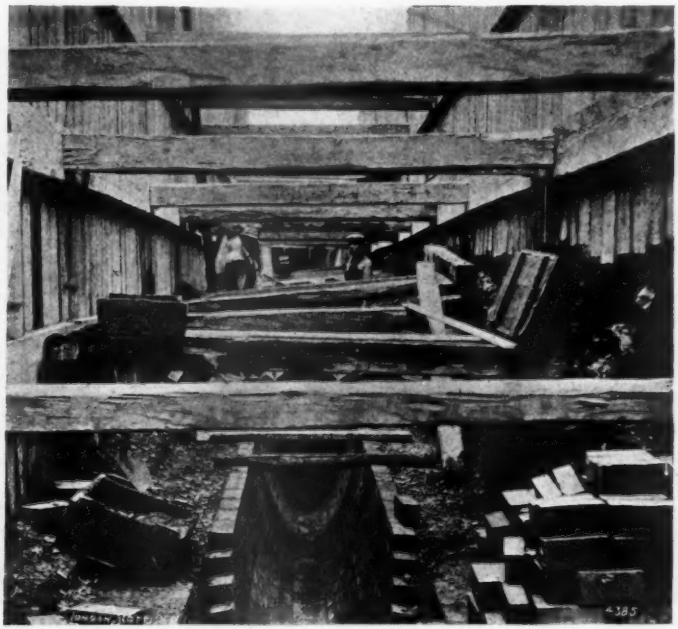


FIG 11.

VIEW SHOWING LAGGINGS AND CONCRETE SIDE WALLS OF SUBWAY.

VIEW SHOWING CONSTRUCTION OF SUBWAY—DEE VILLAGE TO PORTLAND STREET.

owing to the presence in the centre of the street of an existing stone sewer, one of the original city sewers, constructed about one hundred years ago of rubble walls, with a thin stone flag bottom. This sewer was not laid in straight lines, but deviated considerably, and the subway trench, which was 8½ ft. wide between the timbering, often encroached upon the sewer (see photograph). This necessitated underpinning the sewer arch in short sections with 9-in. brickwork, as it was impossible at that time to connect the sewage to the new outfall sewer. The underpinning was satisfactorily accomplished, but was a slow and tedious operation, making the construction of the combined subway and sewer a very slow one. As the work approached Affleck Street the character of the ground again changed. The trench was about 20 ft. deep, the upper 10 ft. being a fine running sand overlying red clay; great care had therefore to be exercised in close timbering the trench, owing to houses and shops closely abutting the east side of the street. The outfall sewer from this point to Academy Street was 4 ft. 3 in. high by 2 ft. 10 in. wide, of the standard egg-shaped section. The type of cross-section adopted for the subway throughout the remainder of its length, above the special length with the flat roof, is as shown in Fig. 7; the greatest depth of trench being reached between Academy Street and Crown Place, where it was 31 ft., the strata being entirely fine sand of excellent quality, which was largely used for making concrete.



OUTFALL SEWER UNDER SUBWAY—SHOWING OLD SEWER TO THE RIGHT.

Between Affleck Street and Academy Street considerable quantities of water had to be dealt with, and the existing sewer caused considerable trouble owing to

leakage. When running full during heavy rainfall on several occasions, the sewer burst through and flooded the trench. When Academy Street was reached the difficulties of construction were increased; from that street one of the main intercepting sewers of the city passes to Union Street (Fig. 1), in the new scheme this sewer was to be connected to the outfall sewer under the subway, the connection had been prepared by driving a short tunnel leading between the two sewers, the old rubble sewer to burst at several places, the whole volume pouring down the subway trench—at that point 29 ft. deep, the excavation having been entirely in sand—and undermining the whole width of the street for a distance of about 190 ft. Fortunately the timbering on the west side fell inwards, and the ground at the top, with causeway stones, etc., in sinking, tended to form a wedge, leaving the sheet timbering on the east side perfectly firm. This was especially fortunate,

SPECIAL CONSTRUCTION FOR SUBWAY ROOF: VIEW SHOWING EXPANDED STEEL IN POSITION BETWEEN STEEL JOISTS, BEFORE CONCRETE WAS FILLED IN.

and immediately under the old rubble sewer in Crown Street, the latter sewer forming a storm overflow from the existing Academy Street intercepting sewer. On August 10th a heavy thunderstorm came on about mid-day; 1¼ ins. of rainfall was recorded in the neighbourhood in eight hours, but the greater part of this amount fell in two hours, and for a space of 30 minutes with very great intensity, causing as, owing to the dangerous running character of the sand, a subsidence might have taken place in the neighbouring houses. To remedy this mishap, after the storm had abated, a trench was opened up on the west side and a new framing of timber put in, the runners in the subway trench were made good again, the whole being strutted across a widened trench of 18 ft., from 10 ins. by

6 ins. walings 30 ft. long, with 10 ins. by 8 ins. pitch-pine struts well braced together. Upon examination the short sewer tunnel for the connection was found filled up with sand, but the timbering was quite secure.

After passing Academy Street the difficulty of inflowing sewage did not present itself, and, though requiring care, the excavation of trench was unattended with any risk. The operations in no case caused settlement in any adjoining properties, although in some cases houses closely abutted the deep trench; this fact speaks well for the excellent way the timbermen did their work.

The outfall sewer above Academy Street is 4½ ft. high by 3 ft. wide, standard egg-shape, with a gradient of 1 in 250. The subway is continued along the street to within 60 yds. of its junction with Union Street: it was originally intended to take it to Union Street, but it was afterwards decided to make the termination at its present position, after representations had been made to the Town Council by the proprietors of adjoining high buildings, as to the supposed risk to their property. Beyond the distributing chamber the outfall sewer was constructed in a tunnel.

Figs. 8, 9, and 10 show plan and sections of the distributing chamber. From this point provision was made for 60 cables being taken from the subway separately into cast-iron socketed ducts of 3 ins. internal diameter, laid in cement concrete. In the chamber is also provided a manhole entrance, and a ½ h.p. Lundell motor and 24-in. ventilating fan, which can be controlled from the electricity station at Dee Village. This fan provides sufficient ventilation in the subway, and the air is remarkably fresh and cool. The exhaust pipe is of cast-iron,

INTERIOR OF SUBWAY WITH FLAT ROOF.

INTERIOR OF CABLE DISTRIBUTING CHAMBER, SHOWING VENTILATING FAN AND CABLE DUCTS (BEFORE COMPLETION).

18 ins. in diameter, and is taken into a special exhaust pit, provided with cast-iron covers in the centre of the street, and is arranged so as to come in the 4-ft. way of the proposed new tramway lines. The subway is lighted electrically by 8-candle-power lamps placed in the roof every 20 ft.

No special methods were adopted in constructing the subway. The ordinary trenches were excavated in the usual way, and closely timbered throughout with 7-in. by 2-in. "runners." Where the excavation exceeded 22 ft. a double setting was used, the top being taken out 10 ft. wide for a depth of 12 ft. and a second setting started the required width of the finished subway, the runners being well driven down into the sand as the excavation was proceeded with; in most lengths straw was carefully packed between the timbering to prevent the sand running. Two 3-ton travelling cranes were used to remove the excavated material. The lower setting of timbering was wholly removed after the walls were built, but in the upper setting most of the runners, and some of the top walings and struts were allowed to remain permanently, to prevent the possibility of settlements or damage to the gas and water mains in the street.

The concrete for the walls of the subway was gauged in the proportions of three parts of granite metal, broken to pass a 1½-in. ring, two parts of sand to one part of Portland cement. Tests were made of the actual strength of the concrete: bars 30 ins. long, 4 ins. square, made with concrete off the stages, were broken between supports, 2 ft. apart, after six months, and were found to have an average breaking-weight of 7 cwts., the average of a few bars being as high as 10 cwts. The weight of a block of concrete cut out of the actual work was equal to 145 lbs. a cubic foot: the average tensile strength of the Portland cement, "neat" tests being 480 lbs. and 560 lbs.

for seven and twenty-eight days respectively.

The concrete walls were constructed between frames as shown in Fig. 11, 1¼-in. loose-planed laggings being used; the concrete was deposited in skips, the level of the walls being kept about equal on either side. As the concrete was put in it was carefully punned and worked into a floating jelly-like mass by means of long flat wooden bars. A length of 30 ft. was, under favourable circumstances, concreted at one time. When the laggings were stripped the walls usually presented a very smooth surface, no filling in, as a rule, being required. The walls were prepared at the top to the required angle for springing the brickwork; at first a brick "springer" was adopted, but it was found afterwards that if the springer was formed with fine concrete it was more satisfactory.

When the side walls were ready the bituminous damp-proof sheeting was laid on the walls (see photograph): the sheets used were 6 ft. wide and cut into lengths of 12 ft., the ends being rolled back out of the way until the arch was turned; when this was done a length of sheeting was put on the top of the arch, the upper part being made to overlap the lower. The jointing of the sheets was done very simply with a special hot-iron (see photograph), care being taken to prevent the iron being used too hot. After a series of arches were turned and concreted, as shown on the drawings, the sheeting was carried across the floor and jointed; the lower part of the concrete floor, to a thickness of 3 ins., was then immediately put in to form a protection. The internal walls of brickwork were then built in cement mortar, and the cast-iron cable-racks fixed every 6 ft. as the lining was proceeded with. Between every cast-iron cable-rack the 4½-in. brick-lining was tied into the concrete by means of flat galvanised iron cramps 2 ins. by $\frac{3}{16}$ in. by 7 ins. long, with ends turned up and down; holes were cut through the sheeting into the concrete walls, and the space left after the cramps were in position, caulked with neat cement.

In the special flat type of subway shown in Fig. 6, the concrete roof was tested for strength. Concrete slabs, 6 ins. thick, gauged 2½ parts of granite metal screened through a 1-in. mesh, and 1½ parts of sand to 1 part of Portland cement, re-inforced with the expanded metal before referred to, were found to bear, after six months, a load of 1 ton per sq. ft. over a span of 3½ ft. without failure; but the writer is unable to say what the real breaking load would be. The breaking load of the 4 to 1 concrete slabs over a span of 3½ ft., *without* the expanded metal, was 8 cwts. per sq. ft. Judging, therefore, from other experiments, it is probable that the breaking load of the re-inforced concrete, over short spans, is four or five times that of the concrete *without* the expanded metal. These loads do not, however, represent the actual strength of the roof, as the bituminous sheeting was covered with an additional layer of concrete varying from 5 to 6 ins. in thickness.

The general type of manholes on the outfall sewer is shown in Fig. 7, the entrance to the sewer forming a groin under the subway, the floor of the manhole being kept to the level of the ordinary dry-weather flow. Access is gained to the sewer by wrought-iron ladders, and the entrances are provided with hinged ventilating covers and dirt boxes. Two independent entrances are made to the subway by means of water-tight manholes at Affleck Street and Academy Street. These will only be used for drawing in cables when required.

The local house-drainage of the east end of Crown Street was connected to the new sewer, by means of 5-in. fireclay pipes taken vertically up the side of the subway, an inspection eye being provided in case of chokage. On the west side a 9-in. fireclay pipe sewer was laid at a sufficient depth to take all the house drains, the smaller sewer being connected to the main outfall at Portland Street; the object of this independent sewer being to prevent the opening up of the street when a new connection has to be made, as it is likely that in a few years Crown Street will change from a residential into a business street.

The subway and outfall sewer was

practically completed by the end of December, 1901. The work has been very satisfactorily carried out by the contractor for the two sections of the outfall sewer—Mr. Peter Tawse, of Aberdeen. The internal arrangements of lighting, etc., were executed by the electrical department, who have also carried out a continuation of the subway, 108 yds. in length, within their own ground, to the new electricity works at Dee Village.

The writer was responsible for the preparation of the contract drawings, and as resident engineer of the Girdleness Outfall Scheme, supervised the construction of the works described.

S. R. J. Conway
1381

The Footbridge for Building the Cables of the New East River Bridge.

By ISAAC HARBY, Jun., Am.Soc.C.E.

One of the largest suspension bridges in the world is now under construction. It is destined for the relief of the traffic between New York and Brooklyn, and will span the East River between Delaney Street, New York, and South Sixth Street, Brooklyn. When completed, the total length of the new bridge will be 7,200 ft., including the approaches, which are, altogether, about 1,200 ft. longer than the existing Brooklyn Bridge. The main span is 1,600 ft. in length, the flooring of which is pitched at a height of 135 ft. above the water level. At the land sides, however, the height diminishes to 117 ft. The width will be 118 ft., and accommodation will be provided for six pairs of railway lines and two wide roadways.

The erection of one suspension bridge from which to build the cables of another has introduced new ideas and instituted a new procedure in the methods of constructing bridges of this type. The cables of the New East River Bridge No. 2, also designated as "The Williamsburg Bridge," are novel in other respects. They are the largest suspension bridge cables ever attempted, and are suspended from towers taller than those in use in any other bridge. These towers are also distinguished by being the first large ones of steel to be used for this purpose.

It is not unnatural, then, that new methods should characterise the work of building such cables.

The engineer in charge of the contract for constructing these cables is Wilhelm Hildenbrand, M. Am. Soc. C.E., who has invented a method of doing better work of this class in a shorter time than has previously been accomplished on any other similar undertaking. His assistant is the writer of the present paper, which was presented before the American Society of Civil Engineers on Nov. 4th last, and forms part of Vol. xxviii., No. 7, of the Proceedings of that Society.

Before entering into the main subject of this paper, a more comprehensive idea of the situation may be given by a brief description of the main cables themselves, the erection of which was the reason for the existence of the footbridge. The writer will also state briefly the conditions encountered at the beginning of the undertaking.

There are to be four main cables, each composed of 37 strands of 208 No. 6 steel wires, laid straight, all of which are finally to be squeezed into one cylindrical cable measuring about 19 ins. in diameter. The distance between the centres of the towers is 1,600 ft. The cables are to be passed over the tops of these, where each one is to rest in a saddle mounted on rollers permitting a motion of 3 ft. in the direction of the cable.

The weight of the main span of the bridge is to be carried directly by the cables, but the parts of the bridge between the towers and the anchorages are to be otherwise supported. Thus the back stays, or shore spans, of the cables will have no load suspended from them. In order to equalise the tensions in the shore spans and the main span of the cables during their construction the saddles are moved back on their roller beds 3 ft. towards the anchorages and held there. This position has been determined by calculation as the proper one to balance the forces caused by the tension in the unloaded cable. The saddles will move forward gradually during the erection of the superstructure of the main span.

The elevation of the centre of the cable where it will rest in the saddle is to be 332·708 ft. above mean high water, and the elevation at its lowest point in the main span is to be 161·027 ft. The cables will be anchored 617 ft. (measured

horizontally) from the centre of each tower, at an elevation of 76·627 ft. The end of each strand will be looped around a cast-steel shoe, held by a pin passed through the end of a chain of eye-bars built in a masonry anchorage.

During the spinning of the wires it will be necessary to support each strand on sheaves a little above the position it will finally occupy in the saddle, and also to hold each end of the strand a little back of its final position in the anchorage. The combined result of this condition will cause the centre of the main span of each strand to hang about 14 ft. higher while it is being made than it will after it is lowered into its final position.

On previous work of this kind a so-called footbridge was used, but it consisted merely of a single path from anchorage to anchorage, used only as a means of passage, and not intended as a working platform. In the case of the New York and Brooklyn Bridge, this footwalk was suspended on two 2⅝-in. wire ropes. When the Cincinnati and Covington Bridge (the second largest suspension bridge now in use) was recently re-built by the addition of extra cables above the old ones, the footbridge there in use was laid on the top of one of the old cables.

The wrapping of the strands and of the finished cable has previously been done from travellers suspended from the cable itself. The regulation or adjustment of the wires has been accomplished by the assistance of cradles, suspended at several points along the line, from which men could reach the wires during regulation.

These methods left much room for improvement, and it became quite evident that if some sort of a working platform could be devised, extending the full length of the cables to be built, and from which the cables could be reached at all points and at all times, a much better cable could be built in a much shorter time.

Thus the demand for such a working platform called into active service the inventive mind of the engineer in charge of the execution of the contract, and he has designed an original as well as an ingenious method of building large cables.

This footbridge is more than an ordinary footwalk from tower to tower. In the main or river span it is a double-deck bridge, and consists of eight continuous footways, four above and four below. The four upper footwalks are about 4 ft. below the line which will be occupied by the strands of the main cable during the time of spinning. The four lower walks are just below the line to be occupied by the cable when the strands have been placed in their permanent position.

These different footwalks are connected by cross-bridges at numerous points, so that an easy communication is afforded from all parts of the structure.

The two land spans are placed directly below the line of the cables, and have only a single deck of four walks.

The whole structure is supported by sixteen wire ropes assembled into four groups of three ropes each, with a single rope suspended above each group. These ropes are stretched from anchorage to anchorage, and passed over the tops of the towers in saddles especially provided for them.

The three ropes composing a cable are clamped together with iron bands every 5 ft., so as to keep the three together throughout their entire length.

These ropes are 2¼ ins. in diameter, and are made of seven strands of galvanized steel wires twisted together. The ultimate strength of each is 208 tons, and the weight 9 lbs. per ft. Each rope was made long enough to extend the entire distance from anchorage to anchorage, about 3,020 ft.

The ends of these cables were made fast to a 30-in. box-girder, spanning an opening in the face of an inner wall of the anchorage, the girder being set at such an inclination that the end of each wire rope could pass through it parallel to its web. The ropes thus passed through are secured by means of button sockets, which bear against the back of the girder.

In order to permit of some adjustment in the lengths of the different ropes forming the cables, and also for convenience in erecting, each is pieced about 100 ft. from each end, and re-united by means of sockets with screw rods passing through them. These rods are 3¼ ins.

in diameter, 6½ ft. long, and are threaded at each end. They permit of an adjustment of 4 ft.

The ends of the four ropes are spaced along the anchorage girder about 1 ft. apart, and the ropes converge to a point on the front wall of the anchorage where they pass over a cast-iron saddle. Between this saddle and the saddle on the main tower they are clamped into one cable, and form the support for the land span of the footbridge.

The clamps are spaced every 5 ft., measured horizontally, and from each hangs a suspender rod of ¾-in. round iron, and an inclined 1-in. suspender reaching sideways. Between each pair of cables is a ⅝-in. tie-rod. The lower ends of the suspenders pass through 3-in. by 8-in. yellow pine beams, upon which the 2-in. by 6-in. flooring is laid. As the slope of the land span becomes steeper as the owers are approached, it was found necessary to break the grade with a step at each beam for about two-thirds of the distance, and the rise of these steps increases with the elevation. Spruce posts bolted to each beam support a ⅝-in. galvanised wire rope hand-rail stretched tight. Frame towers at the middle of the land span carry sheaves for supporting a travelling rope at that point.

The main span, 1,600 ft. in length, is supported for a distance of 400 ft. out from each tower by means of 1-in. suspender rods; and the remaining 800 ft. at the centre of the span, rests directly on top of the cables, and is clamped to them by means of U-bolts passing between two 3-in. by 8-in. yellow pine floor beams bolted together. The suspender rods are hung to the clamps which bind the three ropes together. The lower ends of the suspenders are passed between the two floor beams at each point. The suspenders decrease in length as the distance from the tower increases, until they are discontinued, about 400 ft. out, where the beams rest directly on top of the cables, and are secured with U-bolts. Planking, 2 ins. by 6 ins., with 2-in. spaces between, laid across the floor beams, forms a footwalk. Cleats nailed crossways add to the security of the foothold.

The upper deck of the main span is supported on posts which rest directly upon the beams of the lower deck. These posts are capped with stringers, which in turn carry beams to which is nailed the flooring similar to that on the lower deck. Hand-rails of ⅝-in. galvanised wire ropes are stretched on both sides of each walk. The bridge is stiffened laterally by a cross-bracing of ⅝-in. rods.

Four 2½-in. storm cables are suspended below the main span in the form of parabolas, the vertices of which are about 4 ft. below the vertices of the four footbridge cables. The storm cables cross each other between the centre and the point where they are secured to the columns of the main tower about 50 ft. above high-water mark.

The land spans are held by guys attached to the steelwork of the truss forming the end spans of the main bridge.

In considering the design of the footbridge, the following conditions and requirements were known:

(1) Length of centre span, *i.e.*, horizontal distance between towers;
(2) Length of land spans, *i.e.*, horizontal distance between towers and anchorages;
(3) The exact position of the main cables when finished, and the exact position of each strand while being spun;
(4) The lower deck of the footbridge, when finished, must be about 4 ft. below the line of the main cable;
(5) The upper deck of the finished footbridge must be about 4 ft. below the line of a strand being spun;
(6) The floors of the two land spans when finished must be about 4 ft. below the line of the cable when in position;
(7) Each cable must be accessible from the footbridge at every point along its length.

The general design of the structure being decided upon, the preliminary step in the calculations was the location of the saddles on the towers and anchorages in order to determine the exact span and deflection of the curves.

The cable passes over two saddles on

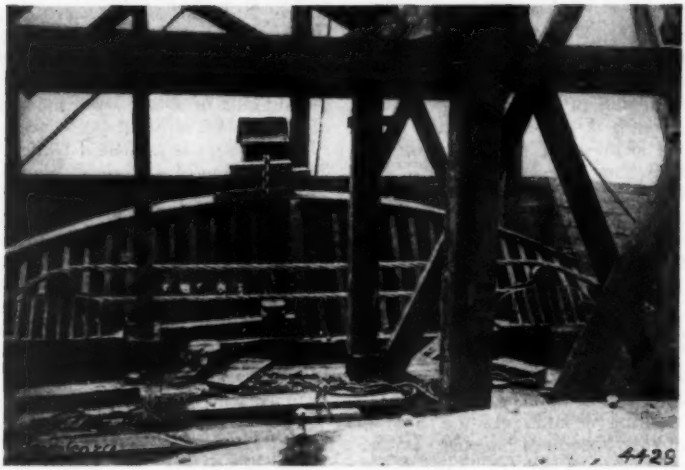


FIG. 1.—SADDLES FOR MAIN CABLE AND FOOTBRIDGE CABLES ON TOWER.

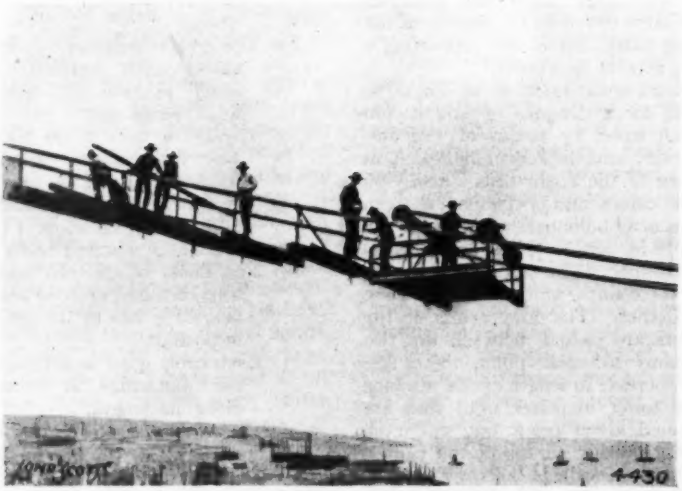


FIG. 2.—ERECTING MAIN SPAN OF FOOTBRIDGE FROM TRAVELLER.

each tower, placed 6 ft. 8 ins. on each side of the centre of the tower.

Therefore: Length of main span = 1,600 − 2 × distance from centre of tower to tangent of curve on saddle.

The position of the tangent point was found approximately by scaling the drawing of the saddle after the line of the cable was laid off on it approximately at the correct angle.

The span being thus determined, the versed sine of the curve had to be found. The elevation of the tangent point on the saddle was known. The elevation of the centre of the main cable at the middle of the span was also known. The distance below the centre of the main cable to the bottom of the footbridge cable = 4 ft. + the thickness of the flooring, floor beams, and footbridge cable. The versed sine of the loaded footbridge cable was thus determined.

The curve of this cable, after the footbridge had been built upon it, would approximate a parabola, and it had been found by experience that the formula of the parabola might be used here with practically correct results.

The load upon the bridge, while not exactly uniform per horizontal foot, is nearly so. The load due to the weight of the cables themselves is greater near the towers where the slope is steeper; but this is partially balanced by the additional weight of the timber work at the centre of the span due to the increased distance between the upper and lower decks at that point.

The total load on the main span is made up as follows:

Timber work	718,000 lbs.
Rods, bolts, clamps, etc. ...	87,800 ,,
Cables	222,000 ,,
Storm cables	55,500 ,,
Guys and storm cable suspenders.	19,500 ,,
Travelling rope	7,200 ,,
Total	1,110,000 ,,

The load per foot $= \frac{\text{Total load}}{\text{Span}}$, and the equation of the curve could thus be determined.

Next, it became necessary to find the equation of the curve of the main cable hanging unloaded. This cable, being of uniform section throughout its length, will hang in the curve of the catenary, the formula for which may be determined from the given position in which the cable is required to be suspended.

By computing an ordinate of the main cable and an ordinate of the footbridge cable at the same point, the position of the footbridge floor in reference to the footbridge cable was determined, and the operation was repeated at as many points as desirable. These ordinates were computed for every 50 ft., and the curve plotted on a scale of $\frac{1}{8}$-in. = 1 ft. After the two curves were laid out, the line of the floor of the lower deck was drawn, it being a constant vertical distance below the main cable.

After plotting these curves, it was found that the line of the lower deck floor of the footbridge nearly coincided with the curve of the footbridge cable for a distance of 400 ft. on each side of the centre of the span. The beams of the lower deck floor, therefore, were attached directly to the footbridge cables for that distance. The lengths of the suspenders for the remaining 400 ft. to each tower were computed from the known ordinates at every 50 ft., and the intermediate ones were found by interpolation.

The next step was to locate the position of the upper deck. The floor of the upper deck had to be a constant distance below the strand while it was being made, this position of the strand being due to its temporary support in a position somewhat higher than that which it will occupy ultimately. Supporting the strand on sheaves over the saddles, and holding the end of it back of its final position in the anchorage cause this condition.

This temporary suspension of the strand will allow it to assume the form of the catenary, the formula for which can be found, and the curve plotted on the same sheet with the other curves. The position of the upper deck floor may then be plotted also. Comparing the ordinates of the curve of the upper deck floor with those of the lower deck floor, the lengths of the posts supporting the upper deck may be determined.

On the land spans the difference in

FIG. 3.—VIEW OF MAIN SPAN OF FOOTBRIDGE FROM TRAVELLER.

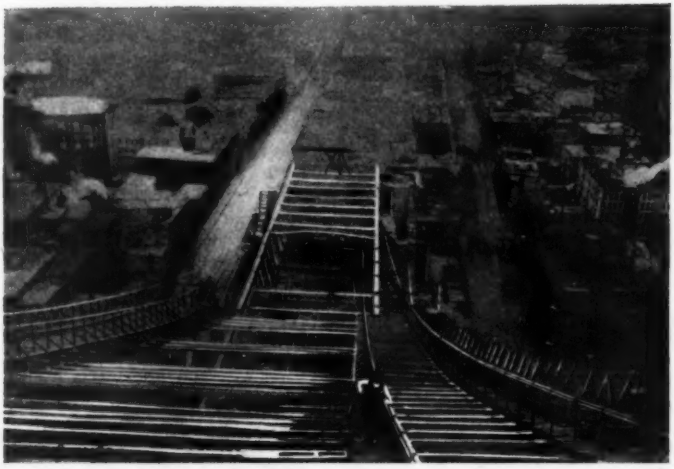


FIG. 4.—LAND SPAN OF FOOTBRIDGE DURING CONSTRUCTION.

elevation between the cable in position and the strand being made was so small that a double deck was not necessary, as the strand in either position would be easily accessible from the same footwalk. The lengths of the suspenders in this span were readily computed by a comparison of the ordinates of the footbridge cable and the main cable in position.

Having settled upon the exact position and design of the finished footbridge, it became necessary to know in what position to suspend the unloaded cables, so that they might hang at the desired elevation after the weight of the structure had been placed upon them.

To arrive at this knowledge an inverse process of reasoning was necessary. It was assumed that the bridge was standing complete, with its cables in a known position and under a known tension. The length of the cable, under these known conditions, was computed from the equation of the parabola. Then it was assumed that all the load had been removed. The cables then would hang in the curve of the catenary. The average tension was then computed from the equation of that curve. The modulus of elasticity of the rope having been previously determined by tests, the difference in length of the cable for this known difference in tension was then found. The new length being determined, and the curve known to be a catenary, its versed sine was readily computed. The elevation of the points of support being known, the elevation of the vertex of the curve was found.

To suspend the cable at the correct elevation, a levelling instrument was set up in one of the towers at exactly the elevation at which the lowest point of the cable should hang.

For the adjustment of the cables in the two land spans a similar process of reasoning was used to find the curve in which the unloaded cables would hang; but as the vertex of the curve lies outside of the points of support of the catenary, the method of adjusting the cable by means of the level could not be used. In this case the transit had to be used; it was set up at a known point between the two supports and in such a position that a line of sight could be taken tangent to the curve of the cable.

The equation of the tangent which passes through the point at which the instrument was to be stationed was found by previous calculation. The inclination of this line being known, the transit was set up, and the telescope inclined at the correct angle of the tangent. In adjusting the cable it was only necessary to hang it so that its underside was tangent to the line of sight of the transit.

These calculations were all based upon a mean temperature. However, as the temperature plays an important part in the position of a cable of such length, it became necessary to make due allowance for such changes. The given position of the main cable unloaded formed the basis for all calculations as to the position of the footbridge. This position is given for a mean temperature of 60 degs. Fahr.

The first figures obtained for adjusting the cables of the footbridge had to be tabulated for a temperature of 60 degs. Fahr.

The elevation for which to adjust the cable in the main span for this temperature had already been determined. If it is assumed that the temperature on the day the cable was to be adjusted would be 1 deg. higher, the increase in temperature would cause an increase in length, but the increase in length would also cause a decrease in tension. This decrease in tension had to be taken into account in determining the amount of stretch due to tension. The true length was thus found for the new temperature, and the deflection computed and tabulated. This was done for all temperatures which were likely to occur during the time of making the adjustment. In the case of the land spans a different tangent was found for the various temperatures, and its angle tabulated to be used as required.

The footbridge cable ropes were shipped by rail from the makers, and were transferred to the foot of the Manhattan tower on the deck of a large tug. Each rope was $2\frac{1}{4}$ ins. in diameter, and about 3,020 ft. long. It came on a reel 7 ft. in diameter

and 4 ft. wide, the whole weighing about 14 tons. A float, 180 ft. long and 25 ft. wide, previously used for the transfer of freight cars, was moored at the foot of the Manhattan tower. Three reels at a time were placed upon this float, mounted on stands bolted to the deck, and placed so that the ropes could be reeled off over the side. Each reel was provided with a cast iron brake-rim over one flange of the drum, around which was passed two turns of 1½-in. manilla line, one end being secured to the deck and the other held by hand.

The end of each rope was unfastened from the reel, raised over the tower, drawn back to the anchorage and secured there. This was accomplished in the following manner. The fall-line from a derrick on top of the tower, operated by a hoisting engine on the float, was attached to the rope by means of a clamp about 60 ft. from its end. The end of the rope was then hoisted to the top of the tower. As the rope unwound from the reel, the loose part passed over the saddles and was placed in temporary rollers mounted on them. Fig. 1 shows the saddles for the main cable and for the footbridge cables, one footbridge rope being in position and the other in the rollers ready to be pulled over. Another clamp was now attached about 10 ft. from the end of the rope, to which was connected a long line running back to the anchorage and operated by means of another hoisting engine located on the end-span truss about half-way between the anchorage and the tower. After the tension had been taken on this "runner," the fall-line on the derrick was relieved of its load and the clamp loosened on the rope, so that it would slide down easily on the rope to the bottom of the tower. There it was once more clamped to the rope, and both engines were operated, one lifting it and the other pulling the end back to the anchorage. It was necessary to readjust the lifting clamp each time it reached the top of the tower, until the end of the rope had arrived at the anchorage.

The socket was next put on and the connection made to the short piece of rope previously secured to the anchorage girder. This operation was repeated until all three ropes, forming a cable, were similarly placed. Each in turn was removed from the rollers on top of the saddles, and lowered into place in the saddle.

The next operation was to get these ropes across the river. This was accomplished with the assistance of three powerful tugboats, which towed the float across the river at slack tide. This time was selected because the course could be more easily controlled, and because at that time vessels could be more easily handled and kept out of the way. The float was towed sideways, with a tug at each end and one ahead to pull. The course was kept as nearly as possible in a straight line between the two towers, and, as it was traversed, the reels were allowed to pay off the rope, which sank and lay upon the bed of the river, the ropes having been previously lashed to the bottom of the Manhattan tower.

The trip across the river occupied about 14 minutes, during which time great care had to be exercised that the reels did not pay off too rapidly. When the Brooklyn side was reached, the float was moored to the tower. It was then found that about 400 ft. of rope remained on each reel. This was unreeled, one reel at a time, and laid along the full length of the deck of the float. About 60 ft. from the end of the rope a clamp was secured, to which the fall-line from a derrick on the tower was attached. The engine on the float operated the line and hoisted the end of the rope to the top of the tower. The loose end was next passed over the tower and placed on the rollers on top of the footbridge saddles. Another clamp was placed near the end of the rope, to which was attached one end of a three-part, ⅝-in., wire-rope tackle, which reached to the Brooklyn anchorage, and was operated by a 60-h.p. hoisting engine there. The clamp was removed from the river side of the rope as it lay over the saddles. The lashings which held it near to the foot of the Manhattan tower were cut, and everything was then in readiness to raise the rope from the bed of the river, and stretch it from tower to tower. Two Government patrol boats guarded the river to prevent passing craft from interfering

with the operation, which was performed at slack tide.

At a signal from a steam whistle on the float (the signal also serving as a warning to passing boats), the engine on the Brooklyn anchorage began to pull the rope over the tower, and gradually drew it from the river bed until it had been raised nearly to its correct position. This operation consumed from four to six minutes. By this time the upper block of the tackle had travelled to the Brooklyn anchorage. The main span was now so nearly balanced with the Manhattan land span that workmen on top of the Manhattan tower were able, by means of a set of hand-tackle, to pull the rope over the tower until it was correctly adjusted.

A man with a transit stationed at the correct point below the curve fixed the position of the rope according to the temperature. Once adjusted, the men on the tower marked the rope in its correct position, and secured it against future movement.

At the same time an additional clamp was being placed on the end of the rope which had been pulled down to the Brooklyn anchorage. This was placed a little above the other clamp, and, attached to the former, was a nine-part manilla tackle with its other end secured to the short rope fastened to the anchorage girder. A tension was now taken on the manilla line by the engine, and the tension on the wire-rope tackle relaxed and the clamp removed. In the meantime the rope was lowered into the saddle on the Brooklyn tower, and everything was made ready for the final pull.

A man with a level stationed in the Brooklyn tower at the correct elevation according to the temperature, gave the signals to raise or lower the rope until it hung at the correct height over the middle of the river. When this was adjusted, the position of the rope was marked on the Brooklyn tower, and secured against future disturbance.

The next step was to adjust the Brooklyn land span. This was done, as on the Manhattan side, by means of a transit set at the correct angle. The rope was lowered or raised to the correct position, which was marked on the saddle at the face of the anchorage as soon as adjusted. The rope was then measured and cut off, and the socket put on and connected to the short rope fastened to the anchorage girder.

This completed the stretching of one of the footbridge cable ropes. The operation was repeated until twelve ropes, assembled into four cables, were similarly suspended. The adjustment of the subsequent ropes was made by comparison with those previously adjusted, but all were finally checked independently.

The placing of the timber work was begun at each tower, and worked downward toward the centre on the main span, and toward the anchorages on the land spans. Each piece was framed and marked as to its location in the structure before being hoisted from the ground. Two travellers for the main span were first erected at each tower, and two for each land span. In each case a traveller ran on two cables by means of grooved wheels connected by an axle to which was suspended a platform large enough to accommodate four or five men. The cable bands, suspender rods, and floor beams were attached to the cable by the men on the traveller. The traveller was allowed to run down the cable in advance of the work. The traveller is shown in Fig. 2. Another gang followed up the traveller and laid planks across the floor beams as fast as they were swung into place. Fig. 3 is a view from the traveller on the main span, looking back at the work just placed. In the main span the material was carried down from the towers by hand, but on the land span each bent was framed complete on the truss below, and hoisted up and connected to the cables by the men on the travellers. Fig. 4 is a view of one of the land spans during construction, in which the travellers have advanced about halfway to the anchorage. It was necessary to keep the work on the two sides of the tower well balanced, so as not to cause the cables to slip over the saddles from undue loading in one span.

The travellers advanced toward the centre of the main span simultaneously

FIG. 5.—LAND SPAN OF FOOTBRIDGE AS SEEN FROM BROOKLYN ANCHORAGE.

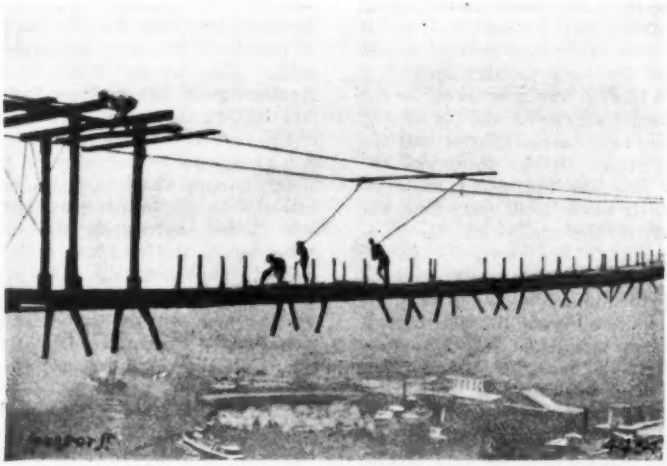


FIG. 6.—CONSTRUCTION OF UPPER DECK OF FOOTBRIDGE.

from each tower, so that the meeting-point was at the centre. When this point was reached the travellers were taken apart and carried back over the footwalk to the towers.

The land span travellers were run down to the anchorages, and taken apart there. Handrail posts were next bolted to the floor beams, and a $\frac{5}{8}$-in. galvanised wire rope for a handrail was stretched along the full length of each footwalk.

Before commencing to erect the upper deck of the main span, four additional $2\frac{1}{4}$-in. ropes were suspended. These ropes were drawn across the bridge from the Manhattan tower, the reel being placed at the foot of the tower. This pulling was done by an engine on the Brooklyn anchorage with a $\frac{3}{8}$-in. plough-steel line, passing over the Brooklyn tower and running on the sheaves on top of the footbridge saddles. Each of the four ropes was hung just above one of the footbridge cables, and rested in the same saddle at the top of the tower. These ropes were suspended at a certain elevation so as to be just below the floor beams of the upper deck, and carry their proportion of the load of the bridge. In each land span they were drawn down and clamped to the other three ropes, forming a cable. Fig. 5 is a view of the land span of the footbridge, as seen from the Brooklyn anchorage, as it passes through the steelwork of the end span.

The erection of the framework for the upper deck was begun at the centre of the main span and carried toward the towers. Fig. 3, is a view of the main span, showing the erection of the upper deck. The material was run down on top of the cable by bridgemen who held each end with a line and ran along the footwalk with each piece, as shown in Fig. 6. When the posts, stringers and floor beams were in place, the 2-in. by 6-in. flooring was laid over the beams, beginning at the towers and working toward the centre. The flooring on the land spans was similarly laid. Handrails of $\frac{5}{8}$-in. galvanized wire rope were stretched on each side of every footwalk, and secured to the handrail posts with staples.

Halfway between each anchorage and tower, and at three points along the main span, were erected frame towers about 12 ft. high. On these were supporting sheaves over which ran a travelling rope.

The four $2\frac{1}{4}$-in. storm cables previously described, each about 1,700 ft. long, were delivered on reels at the foot of the Manhattan tower. The free end was taken to the top of the tower, passing up the land-side, and crossing over the top toward the river on the sheaves on top of the footbridge saddles. The rope was now drawn across the footbridge in the same way as were the cables for the upper deck. They were laid across the lower deck beams and in such a manner that they could be easily pushed overboard. While in this position a suspender of $\frac{1}{2}$-in. galvanized wire rope was fastened every 40 ft. The other end of the suspender was attached to the footbridge cables. The length of each had been regulated by previous calculations, so that when the storm cable became suspended by them it would hang in the form of a parabola.

When all the suspenders were properly connected, the cable was lowered overboard by means of blocks and falls at numerous points until it was hung on the suspenders. The two ends were then pulled in to each tower, and sockets placed upon them. Each was secured to one of the main posts of the tower and screwed up to the proper tension by means of long U-bolts. A view of the main span, with the storm cables and guys in place, is shown in Fig. 7. The footbridge was secured additionally by means of long guy ropes which ran from the main span down to the towers.

Fig. 8 is a view of the completed footbridge as seen from Brooklyn, just back of the anchorage. When the structure was completed, observations were made to determine how near the bridge came to occupying the position for which it was finally intended. The result of the observations showed it to be within a very few inches of the calculated position, which was a great source of gratification to the engineers in charge, as it proved the correctness of the assumptions, the exactness of the intricate calculations

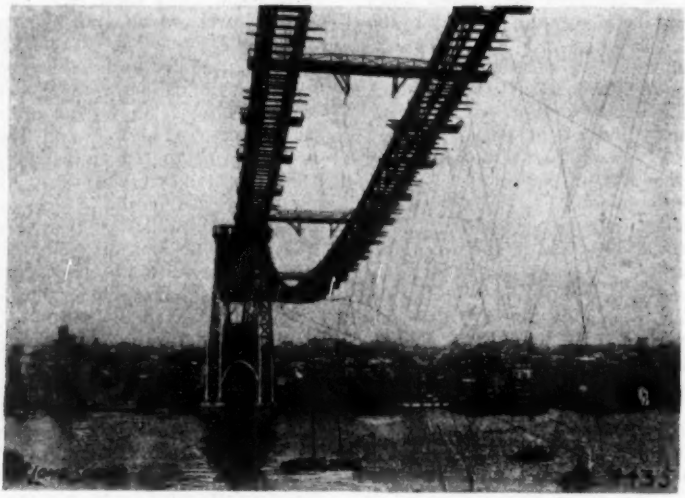


FIG. 7.—MAIN SPAN OF FOOTBRIDGE WITH STORM CABLES AND GUYS IN PLACE.

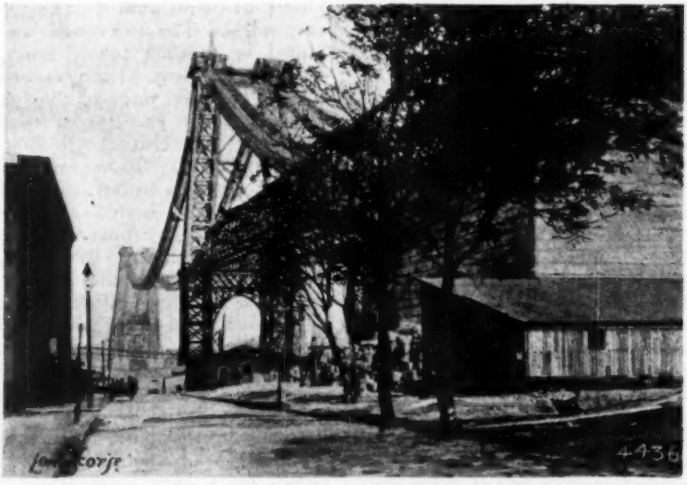


FIG. 8.—COMPLETED FOOTBRIDGE.

involved, and the accuracy of the instrument work.

When the last wire in each main cable had been laid and the last strand adjusted, the usefulness of the upper deck of the footbridge was at an end. The whole of the upper deck work was then removed, the flooring being transferred to the lower deck and the other timber work being kept on the span, so as not to change the loading and consequently the position of the bridge. The upper cables were tied to the lower ones by long U-bolts, so as to make each carry a proportion of the load.

The work of putting on the cable bands and cable covering, and hanging the suspenders, can now be completed from the lower deck of the bridge.

The expectations of what the footbridge would accomplish have not been overestimated, for it has permitted a saving of much time, made the work safer, and afforded a means of building the cables as nearly perfect as it is within human possibility to do. The erection of such a bridge may be usually considered a very hazardous occupation, but in this case not a single accident occurred.

Modern Compound Locomotives.

By CHARLES S. LAKE.

(Continued from page 432.)

Section II.—AUSTRIAN AND AMERICAN LOCOMOTIVES.

(Gölsdorf and Vauclain Systems.)

THE name of Herr Karl Gölsdorf is a familiar one wherever the subject of compound locomotives is under discussion. The well-known system invented by that gentleman, and applied by him to some hundreds of engines in Austria, Russia, Sweden, and Germany, has proved uniformly successful wherever it has been adopted. In his official capacity as Chief Mechanical Superintendent of the Imperial Austrian State Railways (K.K. Oesterrische Staatseisenbahnen) Herr Gölsdorf has been called upon to design some exceedingly powerful locomotives for working both passenger and goods traffic.

As will be seen from the illustrations, he has produced some engines which are remarkable both in respect of general outward appearance and also for the number of special features which are embodied in the details of their construction.

Quite recently four-cylinder locomotives have been adopted upon the Austrian State Railways, but for many years two-cylinder compounds have been employed upon each of the various services which are incorporated under the State Administration. In the course of a letter to the author Herr Gölsdorf says :—

"The distinctive feature of the Gölsdorf system is that no starting valve is required. In the low-pressure valve seating two small live steam inlets are placed, and are so arranged that when the engine is starting, or for any special reason requires additional power from the boiler (the reversing screw being in full forward or backward gear), one of the apertures is uncovered, and the other is closed by means of a rib which is cast in the slide valve.

"Two apertures are situated one at either end of the valve travel. There is no intercepting valve in the receiver."

Fig. 13 is illustrative of this arrangement. The inlet pipes A and A^1 are curved round at either end of the cylinder, and are connected by means of a union to a straight pipe, which is led into the valve chest of the high-pressure cylinder.

Some exceedingly powerful locomotives, designed by Herr Gölsdorf for the Austrian State Railways, were built in 1899. One of their number is illustrated by Fig. 9. The engines of this class are noteworthy, if only on account of their having inside cylinders—a practice not at all common upon the Continent, especially in the case of two-cylinder compounds. There are six coupled wheels and a leading bogie. At first sight it might be supposed that the engines are provided with double frames and outside cranks, as is done upon the English Great Western and other railways ; but this is not the case, as there is no framing inside the wheels in these engines. The reason for this reversing customary practice is that the diameter of the low-pressure cylinder being so great (30 ins.), it is impossible to get both it and the high-pressure cylinder between the frames unless the present method of arranging them is resorted to. This type of engine is being perpetuated. Since 1899 (the year of their introduction) twenty-three have been built, and eleven more are on order, and are to be completed by the end of 1902. These will be numbered 925 to 935 inclusive.

"Heusinger" valve gear is used, and, as will be noticed, the single eccentric which is employed for each set is placed between the outside crank and the frame.

The cylinders are — high - pressure, 530 mm., and low-pressure, 810 mm. in diameter by 720 mm. stroke.

The coupled wheels are $1{\cdot}780^{m}$, and

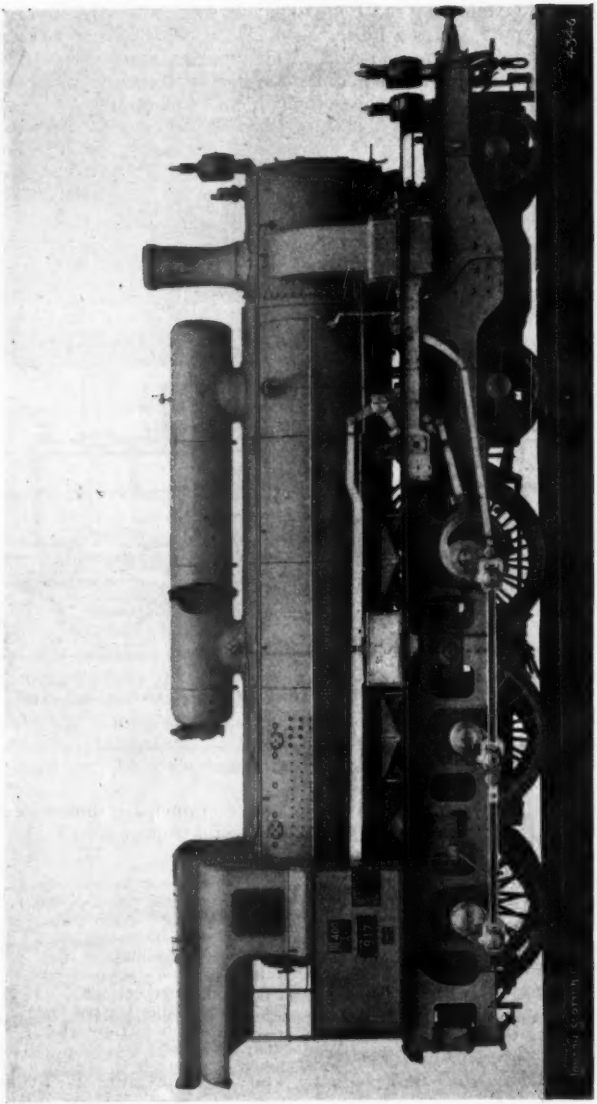


FIG. 9.—SIX-COUPLED TWO-CYLINDER COMPOUND LOCOMOTIVE; GOLSDORF SYSTEM; AUSTRIAN STATE RAILWAYS.

the bogie wheels 994 mm. diameter on tread. The total heating surface is 207·9^{m2}, made up as follows:—Tubes (279), 51 mm. outside diameter = 192·4^{m2}; fire-box, 15·5^{m2}; the grate area is 3·1^{m2}.

The working pressure is 14 atmospheres, and in accordance with usual Austrian practice the "Coale" type of safety valves are fitted.

Fig. 11 represents one of the two-cylinder four-coupled compound express locomotives with leading bogie, of which there are at present some fifty or sixty in actual service, whilst numerous others are in course of construction, the number ordered to be completed by the end of the present year being ninety-nine.

The engine illustrated (No. 10711) is one of the later examples of the type. There are also sixty-eight engines of very similar design, but with smaller low-pressure cylinders and driving wheels and slightly less heating surface. The construction of this earlier series (which bore numbers from 601 to 669) has now been discontinued in favour of the present pattern. In these engines the usual plan of placing the cylinders outside the frames is adopted.

The steam-chests are placed above the cylinders, necessitating the use of outside valve gear. Steam is conveyed to the high-pressure cylinder by means of a supply pipe fixed outside the boiler. This pipe is sufficiently lagged to prevent any ill-effects from exposure to the atmosphere. These engines are employed in working the heavy through International trains (which weigh on the average from 250 to 300 tons), at a speed of 40 to 45 mls. per hour, over sections of the line which include grades of ½ per cent. and sometimes more.

With lighter trains, speeds of 63, 64, and 65½ mls. per hour have been attained in the more level districts

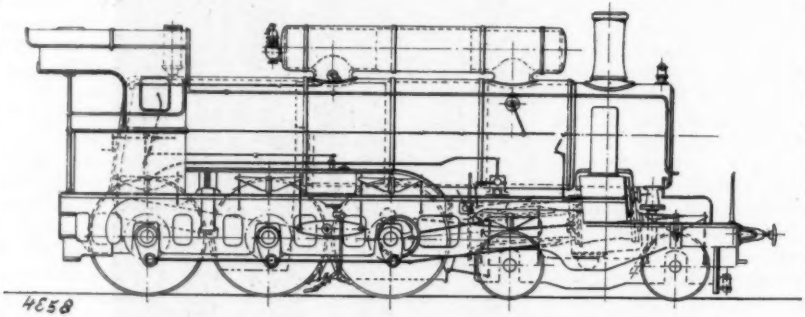


FIG. 10.—OUTLINE DRAWING OF SIX-COUPLED ENGINE, AUSTRIAN STATE RAILWAYS.

The principal dimensions of these successful engines are:—

Cylinders:—		
High-pressure	500 mm. dia.	× 680^{mm}. stk
Low-pressure	760 mm. dia.	
Coupled wheels	2.100^{m}. dia.	
Bogie ,,	995^{mm}. dia.	
Boiler dia. (inside)	1.420^{m}. dia.	
Tubes (No.)	205	
,, diameter	51 mm.	
Heating surf. (tubes)	144.5^{m2}	Total, 154.0^{m2}
,, ,, (fire-box)	11.5^{m2}	
Grate area	3.0^{m2}.	

The steam-pressure is 13 atmospheres, and "Coale" pattern safety-valves are used. The weight of the engine (only) in working order is 55·70 tons (Austrian).

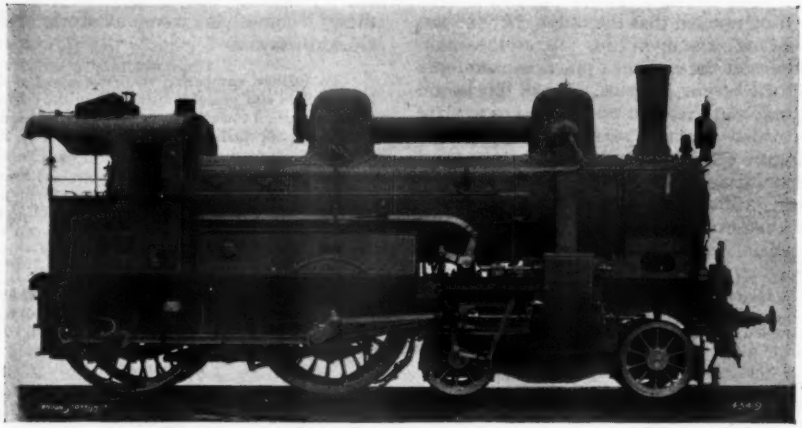


FIG. 11.—FOUR-COUPLED BOGIE, TWO-CYLINDER, COMPOUND EXPRESS LOCOMOTIVE; GÖLSDORF SYSTEM; AUSTRIAN STATE RAILWAYS.

Herr Gölsdorf's latest design is shown by Fig. 14. The engines of these series have four cylinders and an extra pair of carrying-wheels behind the fire-box. They are in every respect the most powerful class possessed by the Administration, and constitute a marked advance in Austrian locomotive practice.

They have been specially designed for running the International trains (which are greatly increasing in weight) at higher speeds than formerly existed, and so far as can be judged by the performances with which they have up to the present time been credited they are admirably adapted to their task. There are at present only five of these locomotives in regular service, but twelve more are on order, to be delivered before the close of this present year.

The low-pressure cylinders are placed outside, and the high-pressure between the frames, with the valves in all cases above them; those of the low-pressure working at an angle to the centre line of the cylinder in order to save space. It

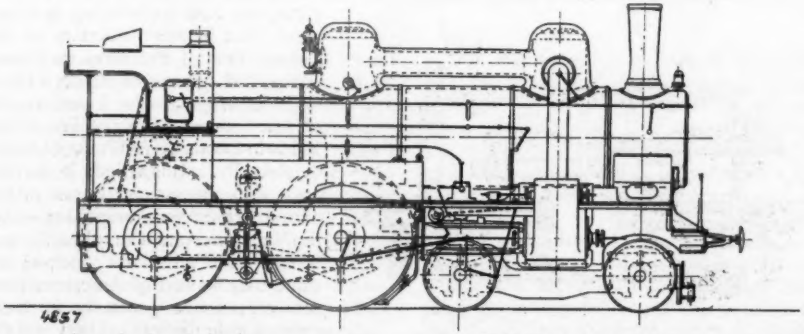


FIG. 12.—DIAGRAM OF FOUR-COUPLED ENGINE, AUSTRIAN STATE RAILWAYS.

will be noticed that the outer shell of the fire-box rests upon the top of the main frames of the engine, a practice commonly resorted to in America. Brake blocks are fitted to the bogie-wheels, but none are provided for the carrying-wheels. The slightly extended smoke-box is supported upon a saddle, which is cast in one with the cylinders and steam-chests. The leading dimensions are—

Cylinders :—			
High-pressure (2), inside		350 mm. dia.	by 600-mm. stroke.
Low-pressure (2), outside		600 mm. dia.	
Coupled wheels		2·140 m. dia. on tread.	
Bogie wheels		1·034 m.	
Carrying wheels		1·300 m.	
Boiler :—			
Length of barrel		3·815 m.	
Diameter (inside)		1·644 m.	
Centre line from rail		2·830 m.	
Heating surface (tubes)	210·9 m.²		
,, ,, (fire-box)	16·6 m.²		
		227·5 m.²	
Grate area		3·53 m.²	
Wheel base (bogie)	2·420 m.		
,, centre of hindmost bogie wheel to centre of driving wheel	1·880 m.		
,, coupled wheels	2·800 m.		
,, centre of hindmost coupled wheel to centre of trailing wheel	1·800 m.		
		9·000 m.	

The steam pressure carried is 15 atmospheres. These locomotives are classed as Series 108, and weigh, in working order (engine only), 68,300 kilogrammes. The tender is carried upon two four-wheeled bogies.

Speaking of the conditions under which these locomotives have to work, Herr Gölsdorf says :—

"To further emphasize the necessity for the large boilers and grates which I use in the engines of my design, I must explain that the coal used is of very inferior quality.

"The evaporative power of 6 lbs. of steam to 1 lb. of coal is only realised on special occasions when we burn no more than about 300 to 350 kilogrammes of coal per square meter of grate (70 lbs. to 85 lbs. per square foot). If we endeavour to improve upon this capacity, clinkered grates are the result."

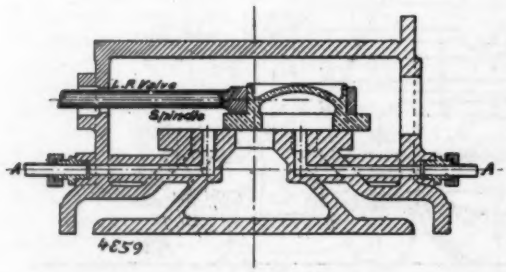


FIG. 13.—SECTION THROUGH L. P. VALVE-CHEST OF A GÖLSDORF COMPOUND LOCOMOTIVE.

Although the locomotives of the United States of America are placed last upon the list in the present article, it must not be inferred that the compound principle is receiving less attention in that land of enterprise and engineering development than in other quarters of the globe. One of the most successful compound systems of modern times owes its origin to the inventiveness of Mr. Samuel M. Vauclain, of the Baldwin Locomotive Works, of Philadelphia, Pa. It is strictly in accordance with the accepted trait in the national character—originality—that the Vauclain system should differ materially from all others ; indeed, the same may be said of American locomotive practice generally, for there exists a wide distinction between the engines of the United States and

those of other countries of the world, both as regards constructional details and general external appearance.

The unique position occupied by the compound system under notice is principally accounted for by the fact that the cylinders are so arranged that, although they are four in number, only two cross-heads, and consequently two connecting rods, are required for communicating motion to the driving wheels.

Furthermore, the use of one valve for each pair of cylinders is rendered possible; so that, altogether, the initial cost of construction is considerably curtailed. This is a strong argument in favour of any device which does not sacrifice efficiency for simplification of detail, and this the Vauclain arrangement certainly does not do. The cylinders are arranged in pairs, with the high-pressure in some cases superposed upon the low-pressure, whilst in others the low-pressure is uppermost, the two piston rods being attached to one common cross-head, as previously stated. The valve chest is cast in one with the cylinders, and is usually placed immediately behind the high-pressure as close as it is possible to get it. No receiver is used. The course taken by the steam in operating the pistons can be easily followed by referring to the sectional view of the cylinders (Fig. 16). For the purposes of illustration the high-pressure cylinder is shown as being raised some distance above the low-pressure. This has been done in order that the valve-chest may be also exposed to view. The arrows shown in the sketch indicate the passage of the steam, from the moment of its entering the high-pressure cylinder to that of its being finally ejected into the atmosphere.

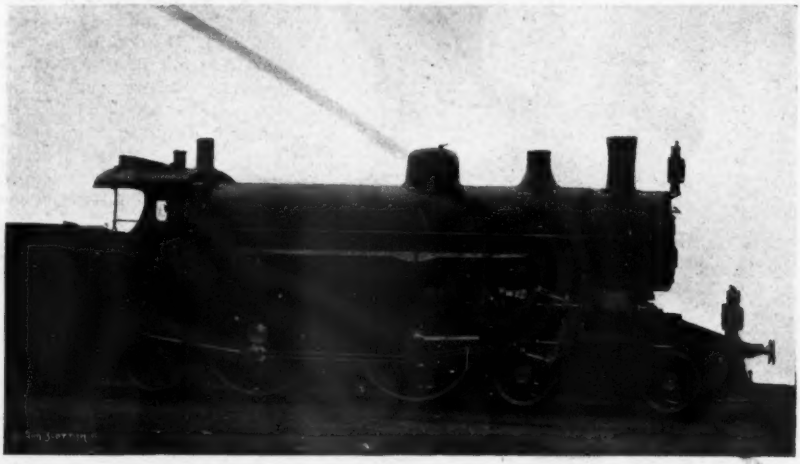


FIG. 14.—TEN-WHEELED, FOUR-CYLINDER, COMPOUND EXPRESS LOCOMOTIVE, AUSTRIAN STATE RAILWAYS.

The starting valve is worked from the cab, and is altogether independent of the valve-gear of the locomotive. A piston-valve (E) is used for distributing steam to the two cylinders. This valve has solid ends (C and C^1), and is provided with an annular cavity around the centre portion of the body.

When the valve is in the position shown in the drawing, steam at boiler pressure enters the valve chamber through the ports A, and passes from there to ports B and thence into the front end of the high-pressure cylinder, and, propelling the

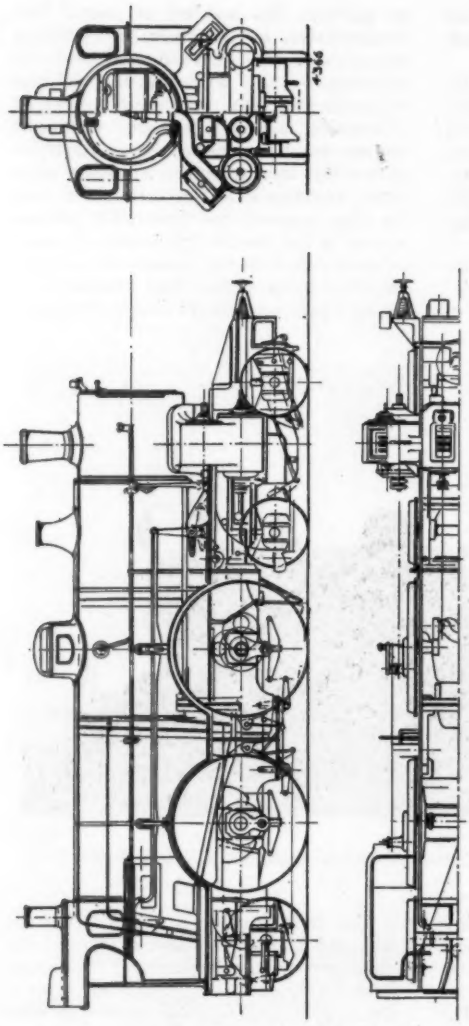


FIG. 15.—DETAILS OF FOUR-CYLINDER, COMPOUND LOCOMOTIVE, AUSTRIAN STATE RAILWAYS.

piston within it, causes the steam which is behind the piston, and which has already been used on the forward stroke, to escape through the passage B^1. Then passing through the valve E it flows into the front end of the low-pressure cylinder by way of the passage D. The low-pressure piston is then caused to travel towards the back end of the cylinder, compelling the steam located there (which has already been used in both cylinders) to escape through the passage D^1 and the circular opening in the body of the valve, and to be finally discharged through the exhaust port and blast pipe into the atmosphere in the usual manner.

The same operation takes place at both ends of the four cylinders.

One of the most remarkable specimens of American locomotive design is illustrated by Fig. 17. This is one of the engines which is daily employed in hauling the trains known as the "Atlantic City Flyers," which are timed to cover the distance between Camden and Atlantic City (the American Brighton), a distance of 55.5 mls., in the scheduled time of 50 mins. The loads are not excessive, usually consisting of five cars of the standard type, and the road is uniformly level; but even with these facts considered the performance is a remarkably fine one, and in order to show that this timing is occasionally improved upon, the following log—the accuracy of which is vouched for by the Baldwin authorities—is appended:—

Stations.	Distance.	Scheduled time.	Actual time of starting and arrival
	Mls.	p.m.	p.m.
Camden - -	0	3·50	3·51½
West Collingswood -	3·1	3·55	3·56½
Haddon Heights -	5·5	3·57	3·59¼
Magnolia - -	7·9	3·59	4·01¼
Clementon - -	12·0	4·02	4·04¼
Williamson Junc. -	17·0	4·06	4·08¾
Cedar Brook - -	19·9	4·09	4·11
Winslow Junc. -	24·5	4·12	4·14½
Hammonton - -	27·6	4·15	4·17
Elwood - - -	33·8	4·20	4·21½
Egg Harbour - -	38·7	4·24	4·25
Brigantine Junc. -	43·5	4·28	4·29
Pleasant Ville -	50·5	4·33	4·34½
Meadow Tower -	53·8	...	4·37
Atlantic City - -	55·5	4·40	4·38¾

The number of cars on this particular occasion was six, containing an aggregate of 285 passengers. The *actual* running time, as will be observed, was 44¾ minutes, which gives an average speed of 74.4 mls. per hour. Several other instances (in which speeds of 73.8, 72.4 and 72.8, have been recorded) are booked to the credit of these engines, which are the property of the Philadelphia and Reading Railroad Company, between whom and the Pennsylvania R. R. (who, by the way, have styled themselves "the mightiest Corporation on earth") a sharp competition for the Atlantic City traffic exists.

Wootten fire-boxes are fitted to these engines to allow of anthracite coal being used. The driver's cab, as will be noticed, has had to be placed over the barrel of the boiler, in order that its occupant may have an unobstructed view ahead, which would be impossible if he were stationed in the usual position with this pattern of fire-box. Telephonic communication is provided between the cab and the foot-plate, so that any instructions which the driver may have to give to the firemen can be communicated without difficulty.

These engines are equipped with the Westinghouse high-speed brakes, which are applied at an initial pressure of 110 lbs. in the brake cylinders, this pressure being reduced automatically as the speed falls to 60 lbs., thus securing the fastest possible stop when the engine is running at speeds of 80 to 90 mls. per hour.

There are many hundreds of Vauclain compounds in daily use throughout the United States. Their use in other countries is restricted to the Canadian Pacific Railway, the few which the French State Railways have purchased, and those in Japan; otherwise the system has no adherents, as far as the author is aware, outside the country of its origin.

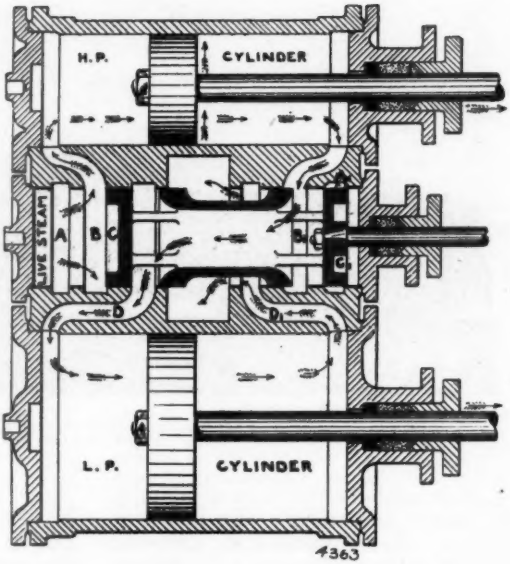


FIG. 16.—LONGITUDINAL SECTION THROUGH H. P. AND L. P. CYLINDERS OF VAUCLAIN, FOUR-CYLINDER, COMPOUND EXPRESS LOCOMOTIVE, PHILADELPHIA AND READING R.R.

The Philadelphia and Reading engines, which, as will be seen, are of the Atlantic type—already referred to—have the following leading dimensions:—

Cylinders:—		
High-pressure	...	15 ins. dia. × 24-in stroke.
Low-pressure	...	25 ins. dia. × 24-in. stroke.
Coupled wheels	...	7 ft. 0 in. dia.
Total wheel base	...	26 ft. 7 ins.
Coupled wheel base		7 ft. 3 ins.
Boiler (diameter)	...	4 ft. 10⅜ ins.
Number of tubes	...	375.
Diameter of tubes	...	1¾ in.
Length of tubes	...	13 ft. 7 ins.
Fire-box (length)	...	9 ft. 6 ins.
,, (width)	...	8 ft. 6 ins.
Heating surface —		
(fire-box)		222·4 sq ft. / 2,540·9
,, ,, (tubes)		2318·5 sq. ft. \ sq. ft.

The tender is carried upon two four-wheeled trucks, and has a capacity for 5,950 gals. of water and 8 tons of coal.

Summarising the matter broadly, it appears that the construction of four-cylinder compound locomotives is becoming more generally favoured by those engineers

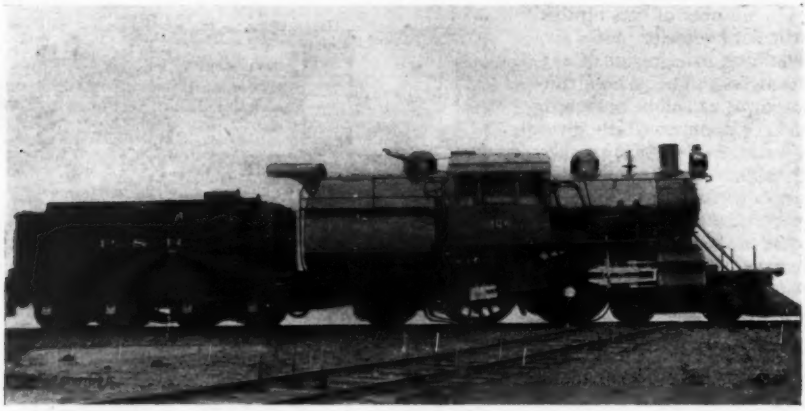


FIG 17.—ATLANTIC TYPE, 4 CYLINDERS, COMPOUND-EXPRESS LOCOMOTIVE, VAUCLAIN SYSTEM, PHILADELPHIA AND READING RAILWAYS.

whose positions as Motive Power Superintendents of large railways bring them face to face with the necessity for providing engines of the most powerful description for dealing with traffic which is yearly increasing, in considerations of weight and speed, and, furthermore, the tendency to reduce the diameter of the high-pressure cylinders and increase that of the low-pressure has become somewhat marked during the last year or so. High steam pressures and large heating surface areas are recognised as being among the most essential adjuncts to the design of a first-class locomotive built for modern requirements. The employment of driving wheels of moderate diameter, chiefly from 6 ft. 6 ins. to 6 ft. 9 ins., has now become very general, although many of the most successful locomotives have coupled wheels 7 ft. in diameter. As time progresses, there appears to be what may be described as an unwritten general understanding between locomotive engineers with regard to many points which were formerly the centres of much professional contention. This is undoubtedly having a gratifying influence upon the working results which are being obtained.

In conclusion, the author has to acknowledge his indebtedness to Mr. F. W. Webb, Chief Mechanical Superintendent of the London and North-Western Railway, Messrs. Worsdell & Johnson, of the North-Eastern and Midland Railways respectively, Herr Karl Gölsdorf, of the Royal Austrian Imperial Railway Administration, and the authorities of the Baldwin Locomotive Works for photographs, diagrams, and information liberally supplied by them for the purposes of this article, and also to Messrs. the Locomotive Publishing Co., for permission to use others of the photographs from which the illustrations have been prepared.

Chas. Lake

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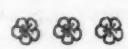
Municipal *v.* Electrical Enterprise.



PROBABLY no other industries have been more prejudicially affected by municipal policy than those relating to the generation and application of electricity. As in many other departments of engineering, satisfactory progress was made in this country up to the point when Parliament interposed with ill-advised legislation. It would be difficult to devise a measure better calculated to take the heart out of private enterprise than the Electric Lighting Act of 1882, which conferred upon municipal bodies the power to purchase electric light undertakings at the expiration of 21 years from the date of the Provisional Order, without the slightest allowance for goodwill and similar assets that are invariably reckoned in all other transactions of a kindred nature. The result was to check in a most marked manner the progress of electrical industry in this country. Some improvement was certainly made after the passing of the Amending Act of 1888, but even at the present time matters are in an unsatisfactory condition. Municipalities sometimes covet the profits derivable from the supply of electric current, and so oppose the schemes formulated by private companies; and at other times they are interested in corporation gasworks, and are prone to stand in the way of progress because they fear the competition of electricity. Even when local authorities make use of powers obtained by them, the ratepayers are seldom to be congratulated on the results. The returns recently issued by the Board of Trade show that out of 149 electricity works owned by local authorities no less than 109 are being conducted at a loss. Advocates of municipal "enterprise" talk very glibly of the profits made, or to be made, in relief of the rates; but such profits are, with a few exceptions, purely imaginary. It is a striking fact that in places where a private company can produce a satisfactory balance-sheet, a corporation generally succeeds in making heavy losses. In proof of this assertion we will take one or two examples. In the city of Bath there was an electric light company which in 1896 was paying at the rate of $3\frac{1}{2}$ per cent. Envying this prosperity, the corporation obtained a Provisional Order, and subsequently took over the works at a valuation which involved the payment of a price less than half the capital expenditure of the company, and even then the corporation made losses averaging more than £1,200 per annum for three years. Again, taking the case of Birmingham, we find that when the Electric Supply Company was started, the corporation, being the owners of gasworks, decided to put every possible obstacle in the way of the new illuminant. But in spite of this the company succeeded in making a profit of £6,000 in 1895, £9,000 in 1896, and £13,000 in 1897. The municipal authorities began to think that so remunerative an undertaking should be in their own hands. Accordingly they bought up the whole concern, and ever since have made annual losses. If space permitted, it would be interesting to enquire into the causes of disastrous losses such as these. Laxity of management and excessive consideration for the working man and his vote have much to do with them, and another controlling factor is to be found in the sale of electric current at unremunerative rates. West Bromwich affords a flagrant example of this unbusinesslike policy. In that borough the charge for electricity was originally 6*d.* per B.T.U. for the first hour, and 2*d.* for each hour afterwards, but owing to the exercise of pressure upon the committee, the charges were reduced to $4\frac{1}{2}$*d.* per unit until a certain consumption had been reached in each quarter, and thereafter, during the same term, at the rate of $1\frac{1}{2}$*d.* per unit. The effect is a heavy loss to the general body of the

ratepayers. Enough has been said to show the utter incompetence of municipal corporations to manage business concerns of this kind, and it is to be hoped that private traders and ratepayers alike will, at no distant date, be protected from the combination of greed and inefficiency which is typified by so many of our local government bodies.

There is another aspect of the question which deserves serious consideration. Speaking generally, it is unavoidable that a local authority having an ambition to provide electricity should be unable to do more than to supply the wants of a limited area. Consequently, as in the notorious example of Manchester and Salford, there may be serious public inconvenience, owing to the jealousies which always seem to exist between adjoining municipalities. It is also the fact that the establishment of isolated and therefore comparatively small installations of generating plant, is not advantageous for the economical production of current. Small units of the kind might, indeed, be necessary if electricity could only be transmitted for a few yards or miles; but in the present day, when facilities exist for long-distance transmission, there is not the slightest need for generating stations in every parish or town, and consumers would benefit greatly if the country were mapped out into large districts, each to be supplied from generating stations included in one comprehensive and skilfully designed system. Schemes of this kind can only be organised by the Imperial Government, by County Councils, or by large industrial corporations. The Government appears to have too much to do at the present time, even if the nationalisation of electricity were decided to be legitimate or desirable; county councils could not be expected to obtain much better results than those shown by municipal corporations in the prosecution of a business requiring technical knowledge and executive capacity, and we must therefore look to private enterprise for the adequate electrification of Great Britain. We have every confidence that most satisfactory progress in this direction would be made if the inequitable facilities for blocking the way were now taken away from municipalities, and if Parliament would promptly undo all the silly legislation of the past. The South Wales Electric Power Company is an example of what private enterprise is willing and able to accomplish. The area to be supplied by this corporation is fully 1,000 square miles, and comprises the whole of Glamorgan and Monmouth, west of the river Usk, excepting only a few places where provisional orders are in force. By the utilization of eight large generating stations and a properly organized system, this company will be able to supply the public with current far more economically and far more efficiently than could be expected from a number of separate local bodies. Yet it is the fact that local bodies almost invariably oppose any comprehensive scheme of the kind, regarding the convenience of the public as of no importance as compared with their own purely local ambition.

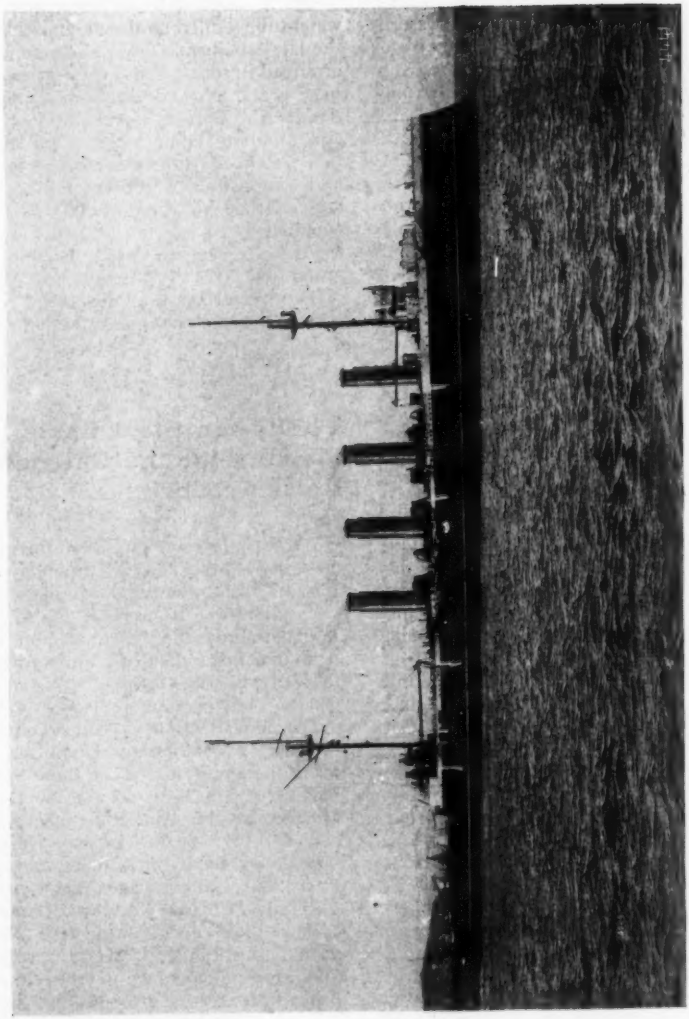
Turning now to tramways, we find the baleful influence of municipal "enterprise" still more rampant. The Tramways Act of 1870, unfortunately, contained clauses affording openings for oppression by municipal authorities, and its effect was largely to check the natural development of the new movement. Under one section of the Act the local authorities were empowered to buy out the undertakings of tramway companies at the end of 21 years, at a bare valuation and without allowance for goodwill or past expenditure, beyond that covered by actually existing plant. When electric haulage began to be introduced, local authorities commenced the construction of tramways within their own narrow boundaries, and so offered obstruction to the development of schemes designed to afford means of communication for various districts. The Act also gave to local authorities a formidable power of veto, which has been relentlessly exercised to stop the development of private lines, or it has been used for the purpose of extorting payment in some form as the price of consent. Heavy rents have been demanded for the use of roads, although such an imposition was never

contemplated by Parliament; other unjust demands include the widening of roads in excess of tramway requirements, the paving and maintenance of streets and roads beyond the limits fixed by the Act, the right to use tramway electric wire-posts and current for municipal lighting, and the issue of free passes for members of local authorities. These are only some of the questionable conditions imposed by local authorities as the price of consent to schemes intended for the benefit of the public, and the fact that these blackmailing tactics have been adopted shows how little such bodies are fit to be entrusted with discretionary power. Apart from such hindrances to private enterprise, the disadvantage of placing traffic facilities in the hands of municipalities is evidenced by the disputes and consequent inconveniences which have arisen between rival authorities, as in the well-known cases of Manchester *v.* Salford and Edinburgh *v.* Leith. We have only to turn to the magnificent work accomplished by the London United Tramways to see how one large company can successfully deal with the problem of road locomotion. The system of this company passes the boundaries of three County Councils and of some thirty district and other councils, and has given to the inhabitants of the metropolis a service that could never have been carried into effect by a number of separate councils, all suspicious and jealous of each other. It may be said that the admirable system of corporation tramways in Glasgow constitutes a proof that a municipality may advantageously provide means of locomotion. We admit the excellence of the installation in Glasgow, but there is no reason why the system should not have been leased to a tramway company which would have brought substantial profit to the ratepayers instead of the present nominal profit. Of course, the assertion is made that a profit of some £12,000 per annum is earned, but if the department were charged with the rent that would be demanded from a company the dead loss would be more than £40,000. Comparing Glasgow with Dublin, where the tramways are controlled by a company, we find that in the latter city 50 per cent. more car-miles are run than in Glasgow, and that 20 per cent. more profit is earned. Again, the experience of the London County Council is that three times as much profit can be obtained from a system of tramways leased to a company as is derivable from those worked by themselves. In these examples we have proof of the fact that business undertakings cannot be successfully worked by bodies formed by popular election. What again is the position at Birmingham? The present state of the tramway service is admittedly execrable. True, it is under the control of private companies, but these have been debarred from the adoption of improvements by deliberate obstruction on the part of the Corporation and by the knowledge that no extensions of leases would be granted. Practically all the leases fall in about January, 1907, and the companies cannot be expected to discard their present plant and spend millions of pounds with so short a term for recoupment. As things stand there is practically a dead-lock—and the public suffers all the inconvenience and loss. The tramway companies are prepared to move with the times, but, as usual, the Corporation stands in the way. Even assuming the Birmingham tramways were bought by the Corporation for two or three millions, and a thoroughly modern system were installed, no sane human being would expect the ratepayers to see a real profit; and, besides, for an efficient system a far larger area is required than is now or ever will be under the control of the city council. Wherever we look, municipal acquisitiveness and greed of power is seen to stand in the way of industrial enterprise, and it is clearly time for the people to awaken to a realisation of the evil thing that has been allowed to grow up in their midst.

The New First-Class Twin-Screw Armoured Cruiser "Good Hope."

THIS vessel, to which the double interest attaches, in that she is the first of a new and important class of cruisers and has had the distinction of being selected to carry Mr. Chamberlain to South Africa, was built for the British Government by the Fairfield Shipbuilding and Engineering Co., Ltd., of Govan, to whom we are indebted for the following particulars and photographs from which the accompanying illustrations were reproduced.

The name originally chosen was the *Africa*, but some time after placing the order it was changed by the officials of the Admiralty as a compliment to the people of Cape Colony, this magnificent and powerful cruiser being the gift of the Colonists to the British Navy. It is the first of the type known as the *Drake* class, of which there are four, viz., the *Drake*, *Good Hope*, *King Alfred*, and *Leviathan*. The *Drake* was launched from Pembroke Dockyard on 5th March last, and the other two were built at Barrow and Clydebank respectively. They are of similar dimensions to H.M.S. *Powerful* and *Terrible*, but differ from that class in certain important respects, notably in having an armoured citadel for protection, and an increased armament; they are not sheathed, and have no poop deck. The principal dimensions are: 500 ft. in length between perpendiculars, and 71 ft. in breadth, with a displacement of 14,100 tons. The armoured and protected sides extend from the stem for a distance of 400 ft. enclosed aft by an armoured bulkhead. The 2-in. protective armour at the bow is of nickel steel, and extends from the lower to the upper deck, affording cover to the men at the 12-pounder guns on the main deck forward. The thicker armour is all of specially hardened steel. There are two armour decks—the lower and the main, the main being thicker in the way of the citadel, and forming its crown; the lower deck has sloping sides which meet the bottom of the armour belt below water. Aft of the citadel the lower deck forms the protection over the steering arrangements, and is of 2½ in. steel. In addition, the coal bunkers are so disposed as to give protection to the machinery. The armament of this cruiser consists of two 9·2 breech-loading guns, fitted in 6 in. armoured barbettes (one forward and one aft); these are served through armoured trunks from the magazines and shell rooms by means of hydraulic power, as well as by hand. There are sixteen 6-in. quick-firing guns (four more than in the *Powerful*), all placed in casemates of 5-in. armour, the rear walls being 2 ins. thick. Of the smaller quick-firing guns there are twelve 12-pounders distributed over the upper decks; while forward and aft on the main deck there are two 12-pounder boat or field guns, three 3-pounders, and nine maxims. There are also two under-water 18-in. torpedo tubes. At the fore end of the vessel is a conning tower of 12-in. armour, with armoured communicating tube to protect the gear for controlling operations throughout the ship. There are two navigating bridges, one forward and one aft. The complement of the crew is 900 officers and men, for which the most ample accommodation has been provided. The furnishings and fittings are of wood, so treated as to make it non-inflammable. An electric installation is arranged for thoroughly lighting the vessel, also six powerful searchlights—four on the bridges, and one on each mast on an elevated platform.



THE FIRST-CLASS ARMOURED CRUISER H.M.S. "GOOD HOPE," BUILT BY THE FAIRFIELD SHIPBUILDING AND ENGINEERING CO., LTD.

The propelling machinery consists of two sets of triple expansion engines, in two watertight compartments, each set having four inverted cylinders working on four cranks; each high-pressure cylinder is 43½ inches, each intermediate 71 inches, and each low-pressure 81½ inches diameter, all adapted for a stroke of 4 feet. The high and intermediate pressure cylinders are each fitted with a piston valve, and each low-pressure cylinder with a triple-ported slide valve with a relieving ring at the back, all the valves being worked by the usual double eccentric and link motion gear. Reversing is effected by means of double cylinder steam engines with gear of the all-round type, hand gear also being fitted. The crank, thrust, and propeller shafting is of forged steel, and hollow. Each of the propellers has a boss of gun-metal fitted with three adjustable blades of Stone's bronze. The main condensers are placed at the back of the engines, and are made of cast brass of oval form and fitted with brass tubes; the condensing water is supplied by four centrifugal pumps of gun-metal, each fitted with an independent engine. The feed, bilge, and hotwell engines are all independent and separate from the main engines, steam for these and all other auxiliary machinery being supplied by a special range of steam pipes. The auxiliary exhaust steam is arranged to discharge to the auxiliary condensers, the atmosphere, and the low-pressure receivers, and can also be used for working the evaporators. There are two auxiliary condensers, each fitted with a circulating pump and a small air pump. List & Munn's patent feed-water filters are fitted to prevent any impurities reaching the boilers. The vessel is also fitted with the usual auxiliary machinery, viz.: a complete distilling plant to supply fresh water to the boilers, and also for drinking purposes; three sets of engines and dynamos for producing the necessary current for electric lighting; two double cylinder direct acting engines with the necessary gear for steering purposes; two complete sets of air compressing engines and pumps, with the necessary air reservoirs and columns for charging torpedoes; and one ice-making machine of the cold air type, including an ice forming chamber, and a pump for circulating water in the air cooler. Steam is supplied by an installation of 43 water-tube boilers and economisers, all of the latest Belleville type. The boilers are arranged in four groups, each group fitted in a watertight compartment; they are designed to work at a pressure of 300 lbs. Air pumping engines are fitted in each boiler room to supply air to the furnaces and combustion chambers; the necessary air for the stokehold ventilation being supplied by large fans. Fans are also fitted for the engine room and ship ventilation.

The vessel on trial developed 31,000 indicated horse power and attained a speed of fully 23 knots.

Thirty-ton Steel Bogie Wagons for the Caledonian Railway Co.

For some time the Caledonian Railway, in common with many other British railways, have been giving attention to the loading of their freight trains; and in connection therewith recently divided an order for 50 bogie-wagons, each of a carrying capacity of 30 tons, between British and American builders *(See Frontispiece)*. To the Leeds Forge Co., Ltd., was given the order for 30 of these wagons, whilst the remaining 20 were to be constructed by the American Steel Car & Foundry Co, of St. Louis. Despite a large Government order for 2,100 under-trucks, and 150 complete wagons for the Imperial Military Railways (Transvaal Colony), the Leeds firm were able to effect delivery of their wagons a considerable time in advance of the American firm, who exceeded the specified date of delivery. The wagons were intended for the conveyance of locomotive coal, but are now, we learn, also being utilised for general merchandise traffic. They are 37 ft. 10 ins. over buffers, 8 ft. 6 ins. wide over all, and 8 ft. 2 ins. high from the rail,

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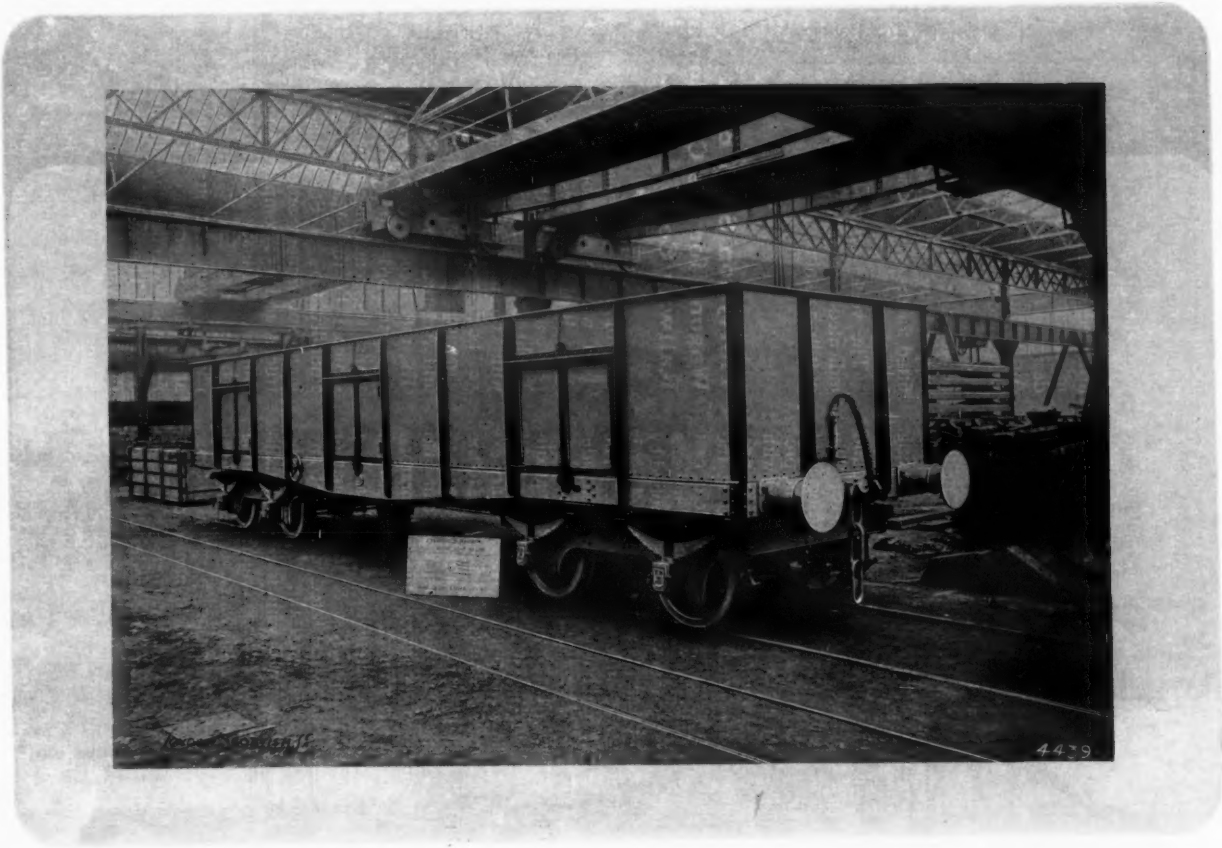
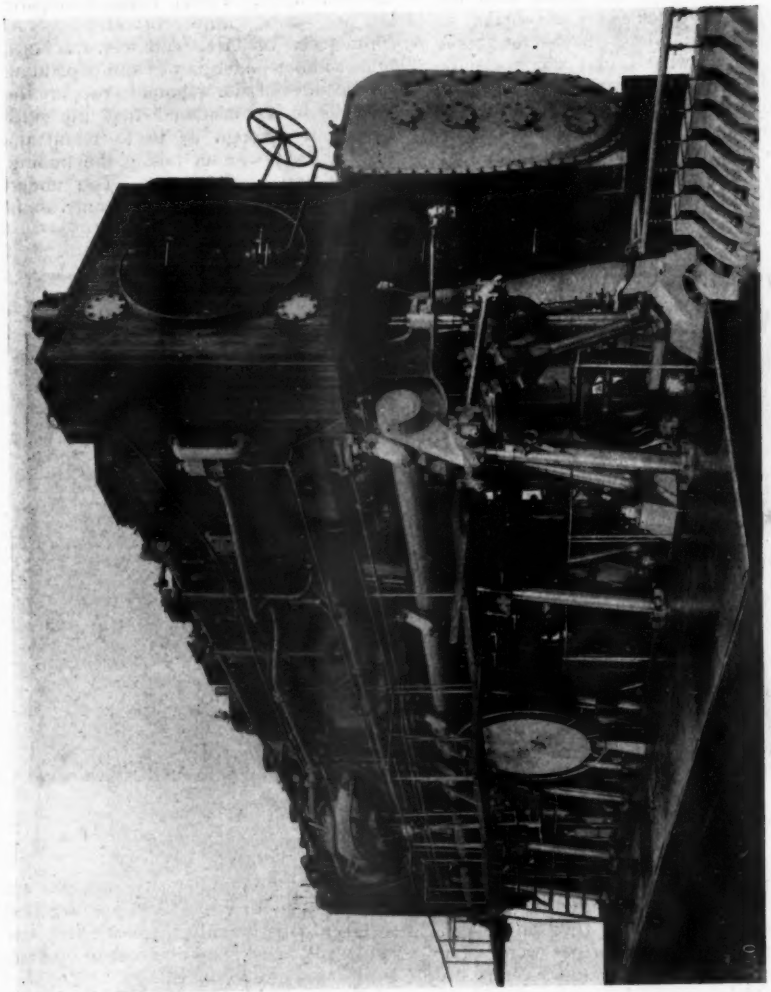


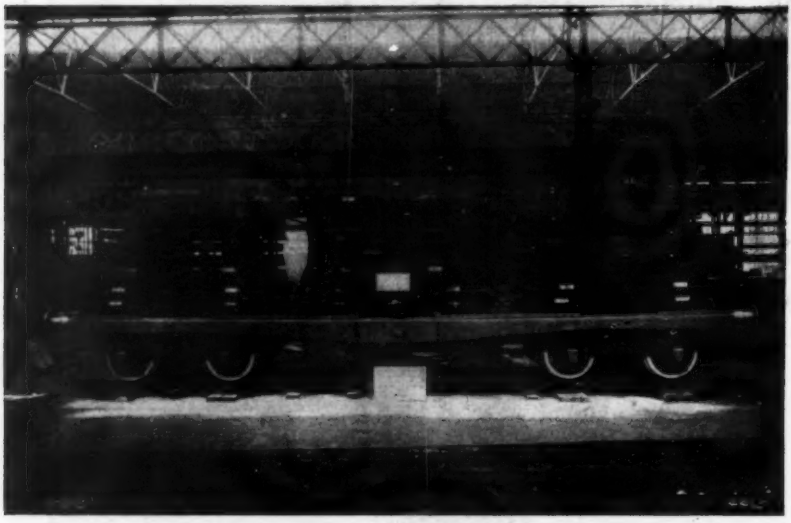
Caledonian Railway 30-ton Bogie Coal Wagon with Fox's Patent Pressed Steel Underframe and Bogies.
Constructed by the Leeds Forge Co., Ltd.

See page 532.



ENGINES OF H.M.S. "GOOD HOPE," FIRST-CLASS TWIN-SCREW PROTECTED CRUISER. CYLINDERS 2/43½ INS., 2/71 INS., 4/81½ INS. DIAM. STROKE 4 FT. 0 IN.; 30,000 I.H.P. THE FAIRFIELD SHIPBUILDING AND ENGINEERING CO., LTD., GOVAN, GLASGOW, 1902.

the inside dimensions being 35 ft. by 8 ft. by 4 ft. 4 ins. The net capacity is 1,208 cub. ft., and the tare weight 12 tons 16 cwts. The wagons are fitted with the Westinghouse quick-acting air-brake, in addition to a powerful hand-screw brake acting on all wheels, and which can be applied or released from either sides of the wagons. The under-frames and bogies are constructed throughout of Fox's patent compressed steel frame plates; and although the wagon is so low in tare weight this has not been obtained at the expense



STEEL WAGONS FOR THE CALEDONIAN RLY.; PHOTO SHOWING LOADING OF THE UNDER FRAMES.

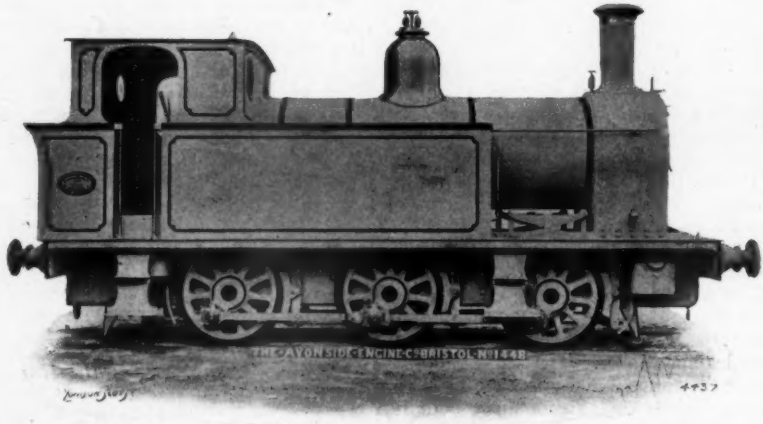
of strength and efficiency, but by careful design and calculation the material is distributed to its very best advantage. The under-frames and bogies were some time ago submitted to several severe tests. The vehicle was loaded with 90 tons of steel plates, 83 of which were distributed over the whole length of the wagons, the remaining seven tons being placed in the centre. Under this load—which is three times the working load—the under-frame showed the slight deflection of $\frac{1}{4}$ in., and the bogies $\frac{1}{8}$ in., whilst when the load was removed there was absolutely no set or injury to any part. The wagons constructed by the Leeds Forge Company are not like a number of other wagons (principally of American construction), built without under-frames and depending on the sides of the wagons to support the load, as it is considered that the sides have quite enough to do to retain the load laterally without taking the buffing, loading and other strains. The under-frames of these wagons have only about one-quarter the number of pieces that are comprised in a frame built up of rolled sections, consequently there are very few joints and rivets, and the cost of up-keep is thus obviously lessened.

The Leeds Forge Company have also designed a 45-ton wagon, of the same dimensions as these for the Caledonian Railway, but with the sides raised to 10 ft. high from rails. These wagons tare about $14\frac{1}{2}$ tons, and show a saving in train length and siding accommodation of over 60 per

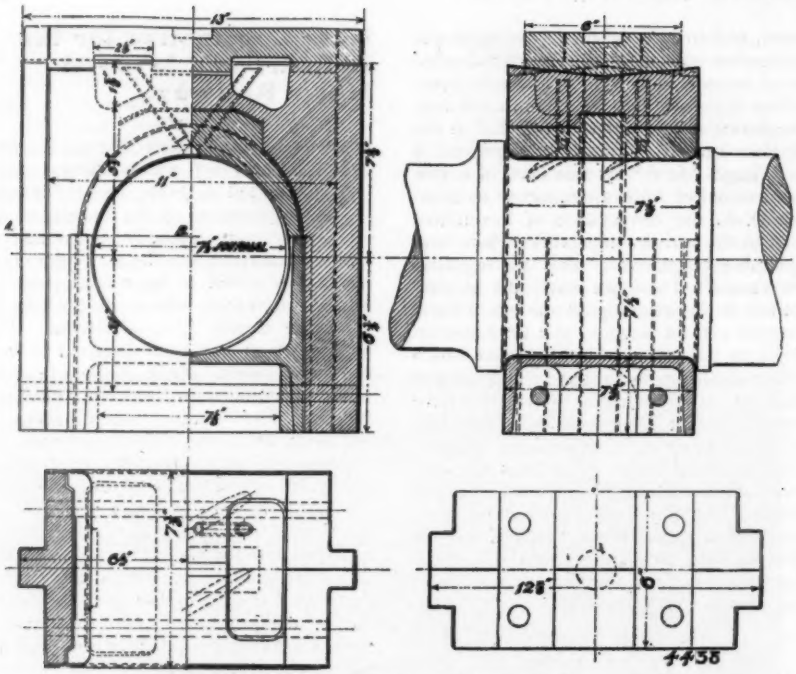
cent., and in tare weight of about 50 per cent. when compared with the four-wheeled 8- or 10-ton wagons now so generally used, whilst it should also be remembered that the saving in tare weight is effected in the double journey. There is at present a very large "field" for this class of wagon (and with but little alteration to terminal plant), in the conveyance of locomotive coal to the various large works where considerable quantities of fuel are regularly consumed. There are practically no difficulties in the weighing, as one end of these wagons can be weighed at a time over an ordinary railway weighing machine which will register up to 30 tons. The visits of English railway officials to America have recently drawn attention to the advisability of the adoption of "high-capacity" wagons. But the construction of this class of rolling stock has for several years been a leading feature with the Leeds Forge Company, and it is a singular fact, that the original designs and machinery were sent from Leeds for making the first pressed steel cars in the United States.

New Locomotive for the Llanelly and Mynydd Mawr Railway.

THE Llanelly and Mynydd Mawr Railway (of which Messrs. John Waddell & Sons, the well-known coal-owners, are the lessees), whose line runs from Llanelly to numerous anthracite collieries in the neighbourhood, have lately added to their rolling stock a powerful new tank locomotive built by the Avonside Engine Co., of Bristol. This engine, which has been designed to work the heavy mineral traffic of the line in the most economical manner, is illustrated below. For hauling heavy trains up the bank, the Company formerly used two engines working together, one having cylinders 14 ins. diameter and the other 16-in. cylinders. The new engine, however, is capable of hauling a similar load without assistance. Owing to the line being in such mountainous country, the conditions are not of the most favourable for locomotives, and to obtain the best results the engine has been made with a short wheel-base and "Cortazzi" traversing axle-boxes, fitted to the leading axle.



TANK LOCOMOTIVE CONSTRUCTED FOR THE LLANELLY AND MYNYDD MAWR RAILWAY BY THE AVONSIDE ENGINE CO., BRISTOL.



DETAILS OF THE CORTAZZI AXLE-BOX, AS FITTED TO THE TANK LOCOMOTIVE.

The "Cortazzi" axle-box is essentially a transverse motion, the top casting (with the hole for the spring pillar in it) is held in position sideways in the axle-box guides, though free to move up or down, whilst the axle-box proper is allowed a lateral movement of $\frac{3}{4}$-in. each side of the centre, sliding on the inclined plane of the top casting—the axle-box guides being made with $1\frac{1}{2}$-in. play sideways, as shown in the drawing. The object of the inclined planes is to bring the axle-boxes back to their central positions when off the curves.

The coupling-rods have a horizontal as well as a vertical joint, and the leading crank pins and brasses are of the ball and socket type, which allows for the movement of the leading wheels. The makers inform us that they have found this type of axle-box very satisfactory, as locomotives built in 1876, and fitted in this manner, after working continuously did not show any appreciable signs of wear in the sliding parts.

The line is 13 miles long, having a ruling gradient of 1 in 40, with continuous curves of four and five chains; and in five miles there is a rise of 500 ft., up which the new engine regularly takes a train of 36 vehicles, weighing 207 tons. The engine has the most modern fittings and mountings, and is fitted with steam and hand brakes acting on all the wheels.

The following are the leading dimensions and particulars:—

Gauge of railway	4 ft. $8\frac{1}{2}$ ins.
Cylinders, diameter	1 ft. 5 ins.
,, stroke	2 ft. 0 ins.
Wheels, diameter	4 ft. 0 ins.
Tyres, thickness	3 ins.
Wheel-base, fixed	6 ft. 0 ins.
,, total	12 ft. 0 ins.
Heating surface (net), tubes	853 sq. ft.
,, ,, fire-box	88 sq. ft.
Total (net)	941 sq. ft.
Grate area	16·5 sq. ft.
Working pressure	160 lbs.
Tractive force (at 70% cut-off)	18,400 lbs.
Tank capacity	900 gals.
Bunker ,, ...	25 cwt.
Weight, empty	35 tons.
,, full	$43\frac{1}{2}$ tons.

Manchester Municipal Technical School.

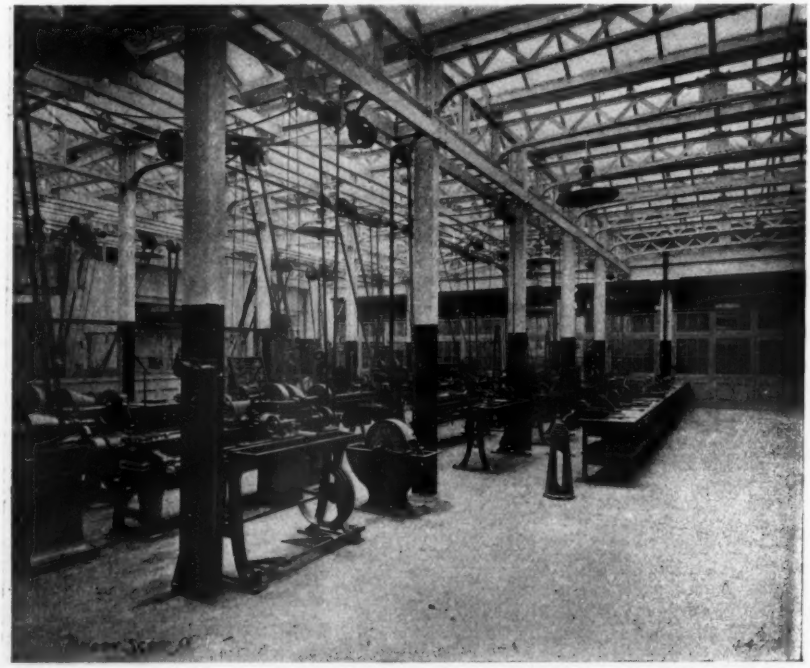
(Continued from page 449.)

MANCHESTER being the commercial centre of the cotton industry, it is perhaps only natural that the courses of instruction and the plant designed to impart a knowledge of the theory and practice of spinning and weaving are of the most elaborate character, and the space set aside for the class rooms, laboratories, and machinery is commensurate with the importance of this industry.

The school contains a complete plant for mixing, opening, carding, combing, spinning, doubling, gassing, reeling, and bundling cotton yarns; for the spinning of waste cotton; for the preparation of cotton and mixed yarns for the loom; and for the manufacture of cotton and mixed goods by hand and power; for silk reeling, throwing, preparing, and manufacturing by hand and power; and, finally, for the chemical, microscopical, and mechanical testing of fibres, yarns, and fabrics. Whenever required, an installation for humidifying is provided.

The department allocated to municipal and sanitary engineering is also of an extremely interesting character, especially in the provisions that have been made for the practical side of the instruction given.

The equipment consists of a commodious drawing-office and lecture-room, well equipped with modern appliances, and a well-arranged workshop, containing benches for 132 students. Each bench is fitted with gas furnaces, oxy-hydrogen apparatus, and all tools necessary for



MANCHESTER TECHNICAL SCHOOLS: THE PRINCIPAL MACHINE SHOP. THE TOOL-ROOM IS SEEN TO THE LEFT.

carrying out the practical work of the department. A great number of examples of completed work are exhibited, and samples of materials used for various purposes are also shown. A portion of the workshop is set apart for appliances used in connection with house drainage, and provision is made for laying and testing the efficiency of drains, traps, and flush tanks, of various kinds, used for drainage purposes.

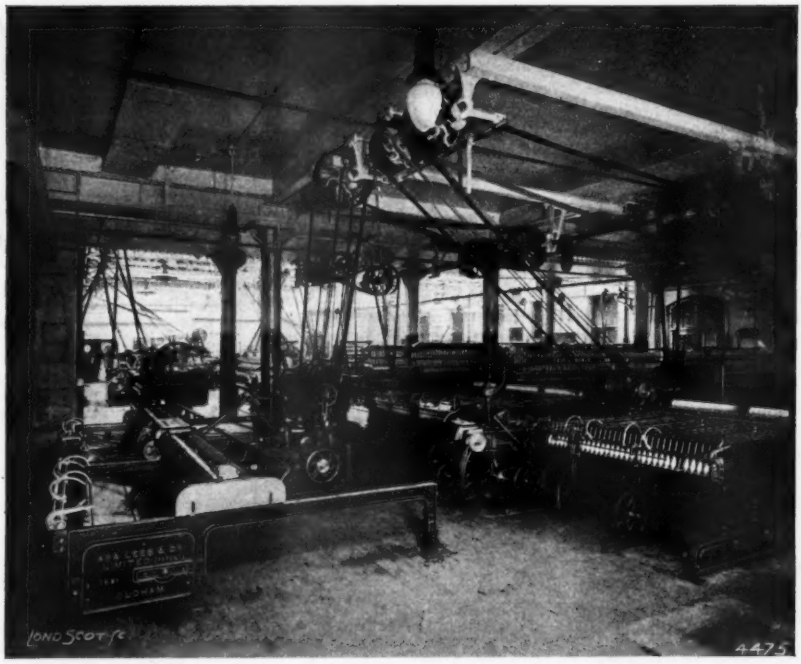
For the purpose of instruction in sewerage work, arrangements are made by which students can lay short lengths of sewers of various shaped sections and of different materials, and can exhibit the use of suitable timber-supports for the sides of the trenches in various kinds of ground. Appliances for raising sewage from low to high levels are fixed and at work. The arrangements used for flushing sewers, and other details of construction, are shown by special apparatus in working order.

Models and apparatus have been provided for illustrating the methods adopted for the purification of sewage and the treatment of manufacturers' waste, and facilities exist for thoroughly testing the suitability of the various cements, the efficiency of traps, and flushing cisterns, etc.

A stock of pipes and special castings has been obtained from the corporation for the purpose of enabling students to deal with the distribution of water.

A large number of appliances are provided for the purpose of enabling the student to deal in a practical way with the ventilation and heating of buildings. When complete, the department will contain a series of boilers and pipes arranged so as to illustrate the heating of buildings

MANCHESTER TECHNICAL SCHOOLS: THE INORGANIC CHEMISTRY LABORATORY.



MANCHESTER TECHNICAL SCHOOLS: A VIEW IN ONE OF THE TEXTILE DEPARTMENTS

by hot water or by steam, under high or low pressure. The workshop is so arranged as to allow the pipes to be fixed and tested by the students as in actual practice, a complete set of modern tools required for this class of work being provided.

An elaborate set of full-sized working examples is in course of construction to illustrate the most approved methods of supplying hot water for domestic and other purposes. When complete, the student will be able to compare the latest English and American practice in this class of work, and to carry out valuable tests and experiments relating to water circulation, domestic boilers, the prevention of explosions and other accidents in connection with this class of work.

A large collection of material used in the making of roads and streets is being made, and special facilities provided for examining and testing the character and properties of materials best suited for certain work. Sections of various forms of roads and streets are being prepared with material used in actual practice.

Mention must also be made of the important department of general technical chemistry, which includes bleaching, dyeing, and printing, paper-making, metallurgy, and brewing. The equipment of this department includes several lecture-rooms and lecture-preparation rooms, the chemical theatre providing accommodation for 150 students. The laboratories are supplied with water, gas, electric power, steam, hydrogen sulphide, vacuum and compressed air, and are replete with apparatus of the most up-to-date description. Besides the main inorganic laboratory, which has an area of 3,900 sq. ft., with bench accommodation for 80 students, there are organic laboratories, an auxiliary laboratory for organic work of special

kinds, a combustion room, gas analysis and water analysis rooms, a physical chemistry laboratory, with an area of 1,230 sq. ft.; brewing, elementary and advanced metallurgical and dyeing laboratories, with which latter is connected a pattern room and a laboratory for the analytical and other chemical work relating to dyeing.

Special arrangements are made, in a suitably-designed building erected contiguous to the school, for practical instruction in bleaching, dyeing, printing, and finishing textiles, and for paper-making. The building occupies an area of upwards of 1,200 sq. yds., and is mainly of one floor, provision, however, being made along its south-east side for an additional storey for a testing laboratory for paper, a lecture room, a dark room, and for a micro-photographic laboratory. This building is equipped with machines of special design and construction, with a view to experimental operations and research on an industrial scale.

A feature of unique interest is the establishment of a department for courses of instruction in the photographic and printing crafts, the equipment of which comprises letterpress composing and machine rooms, lithographic printing room, etching room, electrotyping room, photographic studio and dark rooms, laboratory, lithographic drawing and design studio, and bindery; each with a complete equipment of special appliances and machinery for the effective practical treatment of the subject taught.

In concluding this brief review of the equipment of the school, some mention may be made as to the objects the committee have in view in the establishment and equipment of so magnificent an institution, and this cannot be better done than by quoting from the introduction to the official syllabus :—

"The object of the School of Technology, as its title denotes, is to provide instruction and training in the principles of science in their application to the Industrial Arts, with a view to a right understanding of the foundations upon which these arts rest, and to promote their efficient development. The successful career of a student depends very largely upon his previous general education—unless this is thorough and liberal, no satisfactory progress can be attained in any of the departments of the School.

"The power of clear linguistic expression, and mastery of mathematics, physics, and descriptive geometry are vital to a successful study of the applied Sciences.

"Mere interest in experiment, or in machinery in motion, or even evidence of manual skill and dexterity, without a firm grasp of the above-named fundamenal subjects, are of small avail if the purpose of the student be to attack serious problems in engineering, physics or chemistry, and to fit himself for positions of industrial responsibility. . . . .

"The essential aim of the instruction is the training of faculty through a systematic course of sound theoretical study, and the development of resourcefulness and habits of self-reliance by means of an exact, thorough, and progressive course of laboratory and shop work. . . . .

"It cannot, however, be too strongly urged that the ultimate usefulness and success of these institutions rest entirely upon the complete organisation of a sound system of secondary education, without which no adequate scientific, technical, and artistic training, especially for the leaders of our industries, is possible. It is gratifying to observe that the nation is at last persuaded that the organisation of efficient secondary education is a matter of serious and urgent concern, calling for immediate legislative measures, and that it is recognising with increasing conviction that successful industrial and commercial competition, and a high standard of manufacturing production, depend much more upon the adequate training of the leaders and managers of our industries and commerce than upon that of the workmen, whose efficient education and training for their respective occupations, according to their means and opportunities, must nevertheless receive the most careful provision and the most earnest encouragement."

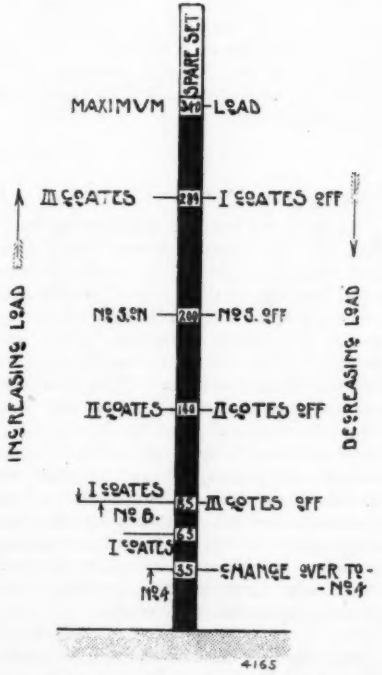
Workshop Practice

4249

Practical suggestions for this section are invited, which, if accepted, will be suitably paid for. Wherever possible, drawings should accompany the contribution; rough sketches will suffice. Nothing will be too poor for a careful inspection. See important announcement in advertisement pages.

The Running of Plant in Central Stations.

THE order of running the plant in electric-light stations to meet the varying demands made upon it varies little day by day. After some experiences of the load have been accumulated, it can be predicted within well defined limits. Then the routine order of running the plant is established once for all, and only departed from under exceptional circumstances. The result is that the men are always prepared for the next orders from the engineer in-charge, and so make timely preliminary preparations. While, if by chance they are taken by surprise, all hands come to the rescue, and get another set to work in less time than one is accustomed to give them credit for. The engineers, after having plotted a number of curves for the winter and summer loads, get familiar with their general characteristics. To a study of these is due their power of foretelling, with more or less confidence, how the load is going to vary. It is instructive to mark on such curves, when the different sets were put on and taken off the load. This shows clearly whether the changes were made to the best advantage or not. When the load is varying rapidly the changes may be made with advantage before the due time for them arrives. The changes made in the running of the plant corresponding to the different loads, for a particular central station, are shown in the accompanying figure. Engineers may find it expedient to make a similar one for their own plant. The figures on the column represent the load in ampères. The plant consists of the following six engines, driving alternators which generate



RUNNING OF PLANT IN CENTRAL STATIONS.

the current given at 2,000 volts: three engines of 280 h.p., output 65 amps.; No. 4, one engine of 120 h.p., output 35 amps.; No. 5, one engine 400 h.p., output 85 amps.; No. 6, one engine of 400 h.p., output 85 amps. The first three sets are similar, and are usually put on and taken off the load in the same order. No. 4 is a light day-load set. Rarely in the afternoons, when the load exceeds 35 amps., it is changed over on to one of the first three engines; in the winter afternoon, to No. 6 set instead. This carries the load up to 85 amps., when one of the three is synchronised with it and left on the load, and so on as shown. The maximum load yet reached is 340 amps. Above this is shown an imaginary spare set. In the central station in question at the maximum load all are running except No. 4 set. Hence the stand-by plant is small, but this will soon be remedied by extensions in progress. With this difficulty in view one of the No. 1 set is put on last and taken off first in order that it may be available as a stand-by set. At night No. 6 set is kept running until 12.15 a.m., when the load falls rapidly to say 35 ampères.

V. R.

Helping the Motor.

On changing over an engineering shop from belt to electric driving (each line shaft being provided with a motor) it was found that one of them was of insufficient power, but apparently ran all right providing that a rope-driven travelling crane was started before the other machines and kept continually running. This, however, was inconvenient, as the crane was only required occasionally and for short periods. With a little thought the difficulty was overcome by placing a heavy fly-wheel by the side of the crane driving-wheel. This materially assisted in steadying the amperage taken by the motor when driving the other machines (principally planers) which were liable to give trouble if all were cutting at the same time.

H. C.

[We assume the fly-wheel to be independent of the crane. ED.]

Re Temporary Repair to Dynamo.

[THE article which appeared under this heading in the October issue has called forth some comment from other contributors as to its practicability; we therefore insert the criticisms and queries referring to the above, at the same time disclaiming the slightest intention of encouraging controversy on the subject.—ED.]

"By doing away with one-half of the winding, we should lower the e.m.f. of the machine by reducing the number of ampère turns." The above is a very common error of opinion; possibly your correspondent has not expressed himself quite clearly, but any reader might be excused for assuming that the ampère turns were reduced by one-half. Such is not the case, however, and although the full magnetic flux certainly depends on the ampère turns, it can easily be shown that theoretically this has not been altered by halving the number of turns, because by doing this the ohmic resistance of the shunt circuit is halved, and in consequence the ampères doubled with the same e.m.f. Hence we have twice the ampères and half the turns, which gives the same magnetic flux as before. I said theoretically, because in practice the heating of the coils would increase their resistance; and this would account for the increased speed of the machine mentioned.

A. E. B.

I was surprised at the suggested remedy for "temporary repair to a dynamo," because it is a well-known fact that by cutting out one coil of a two-pole machine the ampère turns remain practically the same. One would be led to think from the article that the speed would be nearly doubled. This is not so; probably about 10 per cent. above speed with two coils, and this increase would be solely due to extra heating of coil, thereby adding to resistance. Further, the rise in temperature has been entirely overlooked, as in modern machines 60° F. is the usual allowance for coils. Assuming this to be a fair average, we should have the one coil reaching 240°, which would have an exceedingly injurious effect.

D. G. T.

I should like to supplement the remarks on this subject, in order to make the suggestion more applicable. It is stated that "the winding had broken in one of the field coils." In this case it would be best to unwind a few turns, as the fault may be found at the joint of the short length of flexible wire used for connecting the field coils. Again, except the coil has been lately wound, it is never advisable to repair a fault and replace the same wire again, as implied by the writer, as the cotton covering gets "set" in a certain position. In many cases it is scorched or partially carbonised by the heating of the coil. Still, the insulation would remain good, and tends to increase; but when the position of the wires is altered in any way, the brittle covering cracks, and is now anything but pliable. Faults soon develop if it is used again. This applies to all cotton-covered wires; and this difficulty is met when replacing coils in old armatures. If the covering on the coils is found to be brittle, it is best to have the armature re-wound. A better plan would be to unwind the coil as far as the fault, and test the insulation of the remainder. If this be good, replace the wire removed with new wire. Cotton-tape should not be used for insulating such a joint, but preferably cotton covering removed from other wire, as this makes the joint uniform in both appearance and thickness. This may be a hint to wiremen generally.

W. W.

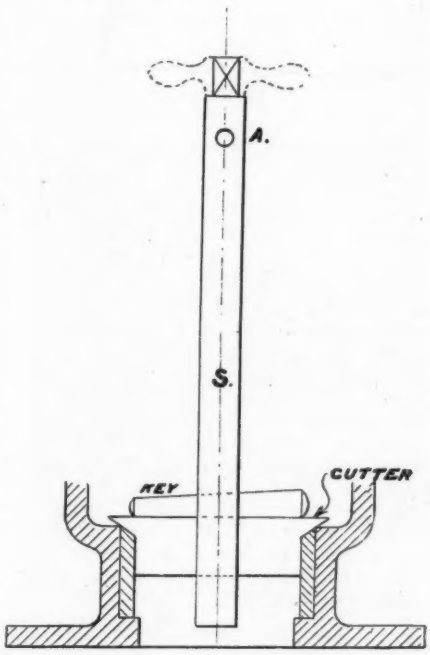
Trueing Valve Seats.

The illustration shows in position a simple and easily-made tool for trueing valve-seats in position. The spindle *S* is made of hard wood, with a hole cut through for cutter and key. A cutter can be easily made from an old file. The valve cover can be put on to steady and keep the cutter central. An ordinary handle may be used, or if a hole be put through at *A* a piece of round iron will do.

ALEX. BLENKINSOP.

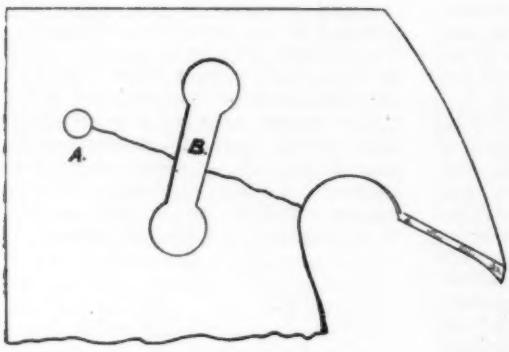
Repairing Cracked Circular Saws.

Accidents to large circular saws arise from various causes, such as striking nails, too hard a temper of the blade, teeth unsuited to the work being done, &c. For instance, teeth with angular gullets are more likely to crack at the roots than those with rounded ones, and also, if the gullets are not large and deep enough to allow of the sawdust escaping readily, they would have a greater tendency to fracture. Instead of discarding a valuable saw, or cutting it down, it may be effectively repaired in the following manner:—



TRUEING VALVE SEAT

Supposing the crack to be a short one—for instance, two or three inches in saws of large diameter—it may generally be stopped from extending by drilling a small hole at the extreme end of the crack (see *A* on sketch). For doing this a drill of the hardest possible temper should be used. I have found Mushet's special steel suitable for this. The drill should be run very slowly, and be well lubricated. It is advisable that the hole should be



REPAIRING CIRCULAR SAWS.

slightly countersunk on each side. A hole of about ¼-in. diameter will, as a rule, be suitable for saws up to 3 ft. diameter; above this diameter a hole ⅜-in. should be drilled. If a saw is badly fractured and it is too deep to be safely drilled, an incision should be made in the plate (as at *B* on sketch), which should be countersunk on each side; fit a piece of steel across fracture and rivet carefully, so as to fill every portion of the opening and countersunk spaces. For deep fractures, two yokes should be inserted; put a soft plug in countersunk hole (shown at *A*), grind and finish, level and smooth with the saw plate. Great care must be taken when riveting to avoid "buckle"; further, plenty of "set" should be given on a saw thus treated to prevent the timber "binding." It does not pay to fit yokes into small saws.

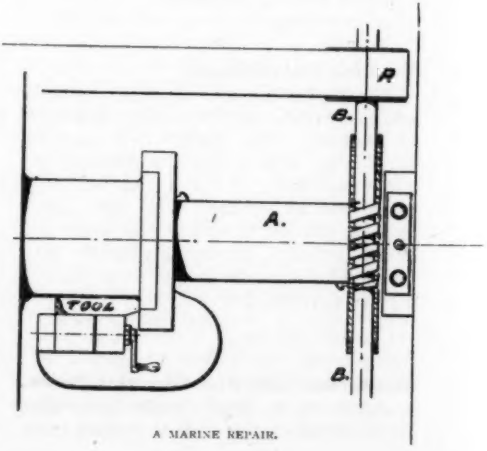
M. O. BALE.

A Marine Repair.

Marine breakdowns and repairs on shipboard frequently present difficulties almost unknown to the artizan in the workshop, owing to the confined spaces and the conditions under which the jobs are done. An illustrative case is trueing up the trunnions of an oscillating cylinder whilst in position, and which was done as follows. A circular casting was made with a recess bored out to fit over the flange of the trunnion, the casting also having a bracket cast on to carry the slide-rest of a lathe. The casting was keyed on one end of a short length of shaft, on which was also keyed a worm wheel, the projecting part of the shaft forming a bearing being supported in a pedestal bolted to an angle plate fixed on the bulk-head. The shaft *A* was driven by the worm as shown, the worm shaft *B* by a strap driving from the donkey-engine to a pulley *P* on shaft *B*; the cut and feed of the tool in the slide-rest being regulated by hand. The operation gave a very satisfactory job, and it has the merit of being original, to suit the emergency. W. PENTLAND.

Correcting Tracings.

'Tis said that men who never make a mistake never make anything worth making. The mistakes made by junior draughtsmen and tracers are many, and this statement is amply testified by the numerous hideous tracings which one meets with in certain engineering works, and the filing cases of some drawing



A MARINE REPAIR.

offices, and a blue print made from a carelessly corrected tracing is indeed a sorry sight. The following method if adopted gives most satisfactory results. If the offending part be small, it may be removed by the judicious application of a *good* ink eraser, and the cloth brought to its original condition, by rubbing over with a block of French chalk, polishing with a piece of blotting paper over the thumb-nail or other hard substance, the final operation being accomplished by burnishing with a cow's tooth.

If the part be large, the above process is long and tedious, but the following method brings about the desired result very effectively. The work to be removed is carefully gone over with a sable brush (No. 5 or 6), a little at a time, with plenty of water, the superfluous amount being removed with blotting paper; this takes out the Indian ink, and the part after being allowed to dry is polished as before with French chalk, blotting-paper, and finished with the cow's tooth. In this manner the cloth is brought back to its original condition and may be inked over without fear. H. H. BROUGHTON.

Threading Tools.

At Figs. 1 and 2 are shown side and end elevations of internal and external threading tools, a distinct departure from the ordinary type of chasers. The former consists of four parts, viz., two clamping-pieces shown in section, the cutter-holder *H* made with parallel shank collar and screwed end to receive cutting disc *D*. The clamp *C* should be made of mild steel, milled all over, the recess in each piece to be about $\frac{1}{16}$ in. less than a semi-circle in order to grip the shank of the holder. The holder *H* may be also of mild steel and provided with a fine thread at the end carrying the cutter. The cutting discs must be made of best tool steel with a sharp, clear cut external thread of the required pitch; two holes o o provide for the use of a peg-key in fixing or removing the cutter. The cutting edges on the discs are formed by milling across the periphery as shown at *E E*, one of the edges forming a full thread, the other backed off to a taper, the former for use in cutting threads to a shoulder, the latter where the opening to be threaded passes through the metal, as in the case of pipe flanges, check nuts, etc. Careful hardening is very necessary in the case of the cutters, to prevent distortion of the internal thread, the heating being done preferably in a gas furnace or jet, and the tempering in a lead bath. This tool will be found far more efficient than the ordinary chaser, as the circular form presents a much longer life with absolute correctness throughout. The external

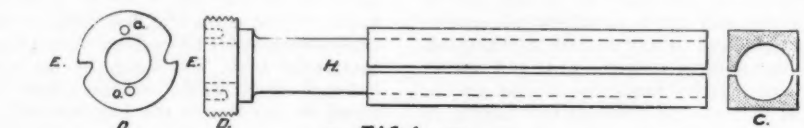


FIG 1

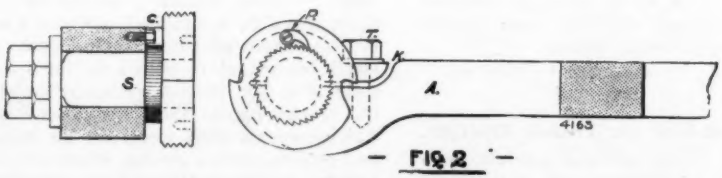
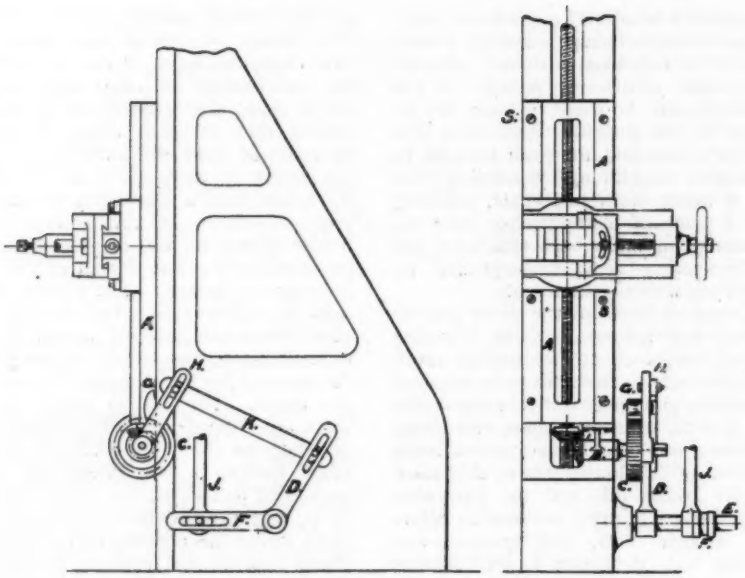


FIG 2

THREADING TOOLS.



SIDE TOOL-BOX.

tool, Fig. 2, consists of a holder *A* carrying a stud *S*, the collar *C* of which is provided with teeth to form a ratchet wheel, a pawl *P* on the side of the holder engages with *C* and prevents the stud from turning whilst in work. The holder is first made as a solid forging, bored and faced to receive the stud, then drilled and tapped for set screw *T*. A saw cut *K* running into the bore allows the stud to be tightened in any desired position, and is further secured by the pawl and ratchet wheel. A left-hand fine thread on the end of the stud prevents the turning of the disc cutter, the form of which and method of grinding being precisely similar to the preceding one for internal threads. Since the use of these particular tools we have got through the work more quickly and with much better results.

SETH FORTUNE.

Side Tool-box on Planer Upright.

Having a large planing machine with two tool-boxes on cross slide, and largely used for planing the feet and steam chests of large steam-engine cylinders, we decided to add a tool-box to the upright, to enable us to plane both feet, steam-chest, and valve face all at one setting. The sketches show the appliance fixed, also method of obtaining feed, motion, etc., which was done without any alterations to the existing arrangement. It has been in constant use about five years, and has repaid for its original cost many times over. It is a very substantial affair, and when in use the ordinary cross saddle of the planer is raised to the top of the housings out of the way.

It consists of a main slide *A* held securely to the upright by the countersunk "cheese headed" set-screws *S*; upon this slide is mounted a swivel tool-box, somewhat after the ordinary style. A small bracket *B* is bolted to the main slide *A* at the bottom corner as shown: this bracket carries the short cross shaft, which carries a mitre wheel on the inside end gearing, with a similar wheel on the bottom of the vertical feed screw, as shown.

On the outer end of the shaft is the spur wheel *C*, and also the lever *H* and pawl *G* which actuates it. The lever *H* obtains its motion from the shaft *E* in the first instance: this is an existing oscillating shaft used to give feed motion to the tool-boxes on the ordinary cross slide through the lever *F* and upright rod *J*, which has a vertical movement regulated in the slot. *D* is a new lever keyed on to *E*, which gives the requisite feed motion through *K*, a lever which couples *D* and *H* together. Both the latter levers have slotted ends as shown, which allows a movement of *K* and regulates the feed to suit the requirements. When the tool is cutting a strong spring is placed between the slide and the tool which forces the tool-box back into position directly it gets over the edge of the metal on the return stroke.

J. GREEN.

A Simple Method of Checking Calculations.

The manipulation of figures at all times presents a certain amount of fascination, but the following examples illustrate a system of checking which may prove useful to many of our readers who may be engaged in calculations involving the use of addition or multiplication of decimals or whole numbers. The method employed in finding the key for addition may be readily understood and extended *ad infinitum*, and although the peculiarities of the figure 9 are generally known they may be further enhanced by reference to its present application.

ADDITION OF WHOLE NUMBERS.

No. 1.

952,100	add *whole* figures = 17, added again	=	8
87,600	,, = 21, ,,	=	3
576,200	,, = 20, ,,	=	2
79,008	,, = 24, ,,	=	6
1,694,908	82 = 10 = 1	19 = 10 = 1	= Key No.

Answer added = 37 = 10 = 1 = Key.

No. 2.

978	= 24	= 6
659	= 20	= 2
834	= 15	= 6
296	= 17	= 8
2,767	= 22 = 4.	76 = 13 = 4. 22 = 4. Key No.

No. 3.

7,634	=	2
8,519	=	5
1,046	=	2
9,200	=	2
1,145	=	2
7,873	=	7
35,417	= 20 = 2.	20 = 2. Key No.

No. 4.

835·22	=	2
198·1	=	1
726·73	=	7
98·54	=	8
887·86	=	1
1,435·52	=	2
4,181·97	= 30 = 3.	21 = 3. Key No.

ADDITION OF MIXED NUMBERS.

78·542	= 26	= 8
31·416	= 15	= 6
31·131	= 16	= 7
43·726	= 25	= 7
185·518	82	28
	8+2 = 10.	2+8 = 10.
Answer added = 28		2+8 = 10.

Any sum multiplied by 9, or by any multiple of that number, has the key number 9—as by the above method—to check its answer.

Examples:—

No. 5.

682
99 (=18=9)

6138
6138

67518 (=27=9)

No. 6.

865
72 (=9)

1730
6055

62280 (=18=9)

Any sum in multiplication having figures which, when added, amount to 9, or to any multiple of that number, has the key number 9—as by the above method—to check its answer.

Examples:—

No. 7.

7335 (=18=9)
437

51345 (=18=9)
22005 (=9)
29340 (=18=9)

3205395 (=27=9).

No. 8.

543681 (=27=9)
85

2718405
4349448

46212885 (=36=9).

JAMES CORBETT.

WORKSHOP QUERIES AND ANSWERS.

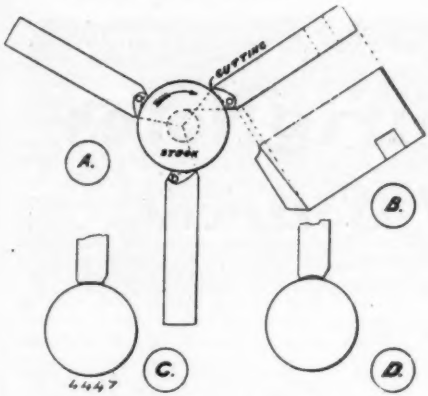
REPLIES.

Cutting Threads on Dies in a Bolt Cutter.

For machines similar to Smith & Coventry's make, where the dies are fixed in a die head, carried on the saddle and operated by a lever. File up the blanks that are to be cut—in this case three—make them of equal length, so that when in position they will be equally distant from the centre of machine. File to the shape in Diagram A, hollowed to suit the diameter they are required to cut; this takes a lot of work off the hob, and a full thread is cut the whole thickness of the die at the same time. It is essential that the dies should be a reasonably good fit, and be carefully put into the die head; if done carelessly, there is a possibility of the thread of one die not leading right for its fellows, consequently bad threads will be cut on the bolts, or the threads will be stripped, especially if the machine is worked to its full capacity to take the whole of the bolt thread at one cut. In these machines a set of small cubes with a square hole through the centre is furnished to suit all sizes of master taps (or hobs) within the range of the machine. This is gripped in the self-centering chuck that drives the bolts. The square on the hob is then slipped easily into this and held by the left hand, the saddle moved up by the right, with the dies wide open. When over the hob the lever is pressed over, closing the dies firmly on to the hob, and as the hob cuts its way into the die blanks, which will be felt by the hand pressing the cam lever, the pressure is gradually applied to enable the hob to continue cutting until a full thread is obtained. (Note: Don't spare the oil, and don't force the cut.) The hob will require to run through the dies several times to bring up a full thread. If the hob cuts badly or is forced, the thread is dragged on the sides of the vee, becoming scored and deformed; and a reproduction of these inaccuracies on the bolts will result, together with indifferent cutting and heating of the dies. Where a loose poppet head is used, the thread end of the hob can be carried by the poppet head centre; but this is not important. What is more necessary is that the square cube driver in the self-centering chuck should be gripped truly—these self-centering chucks have a nasty habit of being everything but self-centering when in the hands of unskilled attendants; and a little packing is sometimes required to make the driver run in line. No good results in forcing the cut on the dies too quickly, let them feel their way up the hob. Cast steel has a habit of dragging on the threads that is very trying to the tool-maker, and if the thread is cut roughly it is cheaper to throw away the dies than to attempt to use them; they will be a never-ending source of trouble in bad work. When a full thread is formed in the dies great care must be exercised to prevent the tops of the threads in the dies wedging and seizing in the bottom of the thread of the hob. When a full thread has been formed, and it is found desirable to cut still further to bring up the sides of the vees to a smoother and fuller condition, the tops of the vees in the dies should be carefully filed off the required amount, and the dies cut again up to a full thread.

For machines that carry the dies in a die chuck on the fast head spindle, the method of carrying the hob is reversed: the method of cutting and operating, and the precaution to be taken is the same in all cases. For dies for hand work the die holders can be held in the vice and the tap turned by a wrench.

After the dies have been cut to the required condition, take out, file the clearances shown, and harden a straw colour. It sometimes happens that machine dies have a desire to pull off a thread or two on the bolts, especially where the dies are wide and have several threads in; the cause is usually roughness of the vees, and can often be remedied by backing off a thread or two as shown; in fact it has been found in some cases, where the dies have been pronounced incorrigible, they have cut



CUTTING THREADS ON DIE.

sweetly after all the threads, except about the first 2½, have been backed off. Sometimes a die will break off two or more threads: when this happens the dies should not be destroyed, but the set should be ground similarly with equal numbers of threads, and put in again. Dies will often cut better with half their number of threads than with their proper complement.

View *A* shows three dies in working position. The cutting edge is bevelled slightly about radially as shown by dotted lines, the other edge is backed off a little more for clearance, about tangential to the small dotted circle. Dotted arcs may be noticed at *O*. For troublesome dies it is sometimes found that backing off the threads, as shown by the dotted arcs, is a good remedy. *B* is a side view of one die, showing clearance filed on top, bottom, and side of die. The diameter of the hob that is to cut the dies is a matter upon which a definite understanding cannot always be obtained. I have tried hobs of the same diameter of the stock to be screwed, also both larger and smaller in diameter than the stock to be screwed, and have found that dies cut with a hob a little smaller than the thread to be screwed, do their work more easily and effectively than dies cut with a hob larger than the stock to be screwed. *C* and *D* are given as illustrations showing the effect of large and small hobs. In *C* the dies have been cut by a hob larger than the stocks to be screwed, it will be noticed that the middle portion of the die rubs the stock before the cutting edge. *D* shows the die cut with a hob smaller than the stock; the cutting edge comes to its work at once, and if it is desired to give the threads more clearance, shown by the dotted arcs *O* in *A*, the cutting edge can be brought more freely to the work. In both *C* and *D* the arc of contact is exaggerated to more clearly illustrate the difference.

WORKS MANAGER.

REPLY TO W. D.

Iron *v.* Steel.

1. The mild steel of weldable quality, now so much used for smiths' work, is too soft for the purpose, and unable to bear the pressure that can be safely imposed on good wrought iron.

2. During an experience extending over many years, I have found that the wear on mild steel rods of different kinds was considerably more than those of iron; further, that in three-throw cranks or shafts with three journals, breakages were more frequent when the bearings got out of line.

3. I have had the best results from good hard steel rods for steam hammers, the mild steel ones in this case not wearing as long as the wrought-iron ones. When in charge of a rail-rolling mill I got excellent results from rail-steel made by the Bessemer process, and containing about 0·3 per cent. of carbon.

4. Wrought-iron is successfully case-hardened with potash or by other methods, whilst mild steel subjected to this operation is often unsatisfactory.

REPAIR ENGINEER.

Engineering Notes From all Sources

CONSTRUCTION.

Recent Tunnels under the River Thames.

THE Greenwich Footway Tunnel was the second tunnel beneath the river Thames undertaken by the London County Council, with a view to improve the means of communication between the districts lying north and south of the river, and east of the Tower Bridge. It was intended to replace the existing steamboat ferry between Greenwich and the Isle of Dogs, to the working of which, in a crowded waterway like the Thames, there were serious objections and hindrances. The work had been commenced in June, 1899, and was now nearing completion.

The subway consisted of a cast-iron tunnel, 12 ft. 9 ins. in diameter, connecting two shafts, 43 ft. in internal diameter and 1,217 ft. apart. One of these shafts was situated in the Island Gardens, Poplar, the other being immediately behind the Ship Inn at Greenwich. Access to the subway was afforded by lifts and circular stairways.

The tunnel was similar in character to other iron tunnels recently built in London. From each shaft it dipped towards the centre of the river with a gradient of 1 in 15, the middle portion being on a gradient of 1 in 277, falling towards the Greenwich shore. These gradients were entailed by the advisability, from motives of economy, of limiting the depths of the shafts, and by the necessity of complying with the stipulation in the Act, that the level of the tunnel should be such as to allow of dredging a channel in the river, 500 ft. wide and 48 ft deep, at high water.

The caissons were 35 ft. in internal, and 43 ft. in external diameter, and were formed with two steel skins, the 4-foot space between them being filled with 6 to 1 Portland-cement concrete. The skins were formed of horizontial rings built up of plates, which were generally about 4 ft. 9 ins. in depth, and varied in thickness between $\frac{3}{8}$ in. at the bottom of the caisson, and $\frac{5}{16}$ in. at the top. After describing, generally, the shafts, the Author pointed out that their special features were the absence of any taper on the outside of the caisson, and the provision of two air-tight floors, the one permanent and fixed immediately above the cutting edge, and the other temporary and fixed above the tunnel-opening. The sinking of the caissons which had been done under compressed air, had been greatly facilitated by these arrangements, and had been effected with very uniform progress, and without any disturbance of the surrounding ground.

During the sinking of the caissons, the opening in each shaft for the tunnel had been closed by a "plug" formed of steel plates fitted between girders in such a way as to be removeable singly when the shield was ready to start. The operation of removing this steel plug by gradually substituting, 4 ft. behind it, a timber diaphragm, and filling the space between this diaphragm and the face with pugged clay, was briefly described.

The cast-iron lining was similar in character to that used in previous works of the same kind, but some improvements had been made in details to obtain better water-tight joints. All bolt-holes were made with a short portion beveled off, and when the bolts were put in, lead washers were put on them, and, on the bolts being screwed up, the lead completely filled the space round the bolts at each end made by the beveled edges of the bolt-holes. This arrangement had proved very successful, and comparatively few bolts had been found to be leaking when the air-pressure was removed. Into the joints between castings, soft lead wire was hammered before caulking. The shield was of the "trap," or "box" type. The Author gave a short account of the evolution of this form of shield, with diagrams of successive shields built on this principle. The one used for the Greenwich Tunnel was 14 ft. 6 ins. in length,

and had an external diameter of 13 ft. The cutting edge was made in thirteen segments, each segment having two 6-inch teeth cast on it, and immediately behind the cutting edge was a circular built box girder. Certain alterations suggested by experience had been made in the shield, the nature of which was fully described in the paper, as well as the method of tunnelling, which differed from previous similar work only in the use of face-rams for holding up the timbering of the face. The rate of progress had been exceptionally rapid, an advance of 10 ft. per working day having been made over all the tunnel, except a short length in open ballast on the Greenwich side. This the Author attributed mainly to the favourable character of much of the material excavated.

After giving some general statistics as to the health of the men employed, the Author described an arrangement for drawing vitiated air from the working-front of the shield. An attempt had also been made to eliminate the carbonic acid from the air supplied to the tunnel by means of caustic soda. With this object, an apparatus consisting of boxes or rectangular tubes of wood, one above the other, open at one end, and having sliding doors at the other end, had been devised. The ends fitted with doors were connected to the air-inlet of the tunnel by a conical box, the connection with the air-pipe being made air-tight by a flexible joint. By opening one or other of the sliding doors, the air could be made to pass through either the upper or the lower tube as required. These tubes had removable sides, and each contained eight movable wire boxes containing pumice stone broken small, which, before being put into the tubes, were dipped in a saturated solution of caustic soda. A table of results was given, showing some reduction to have been made in the proportion of carbonic acid present in the tunnel.

The second paper described the work of tunnelling under the river Thames for the Baker Street aud Waterloo Electric Railway.

In passing beneath the Thames, the tunnels, elsewhere wholly in London clay, encountered a bed of clean gravel and sand, lying in an abrupt depression of the clay surface. This freely water-bearing bed had necessitated construction under compressed air. The two tunnels, each for traffic in one direction, ran parallel and on the same level for a short distance under the river from the Victoria Embankment, at the bottom of Northumberland Avenue; after which the east (up) tunnel had a rising gradient of 1 in 111, and the west (down) tunnel a falling gradient of 1 in 107 towards the south side of the river. On passing under College Street the up tunnel was vertically over the down tunnel.

The temporary stage, from which the working-shafts in the river had been sunk, was constructed on piles, parallel with the Embankment, and 150 ft. away from it. From this stage a temporary foot-bridge led to the Embankment. A stage, 370 ft. by 50 ft., held the contractors' plant and necessary buildings. Two 16-ft. shafts having been sunk, tunnelling northward had been begun from one of the brick chambers at the bottom in February, 1899; but southward the river work had been begun in March, 1900.

The shield for tunnelling through the gravel was provided with a hood in front to cover the men during excavation, and a fountain trap behind, to afford an air-seal against a horizontal water-service, should a run of water at the face threaten flooding of the tunnel. Under the forward top screen of this trap, which was close behind them when working, the miners could escape in case of necessity. The appliance had proved perfectly successful in accomplishing its purpose. Laterally the shield was divided into two halves, ahead of the trap, by a vertical girder, which enabled a limited face in one half to be attacked, after any accident to the face-planking due to a "blow." The other essential features of the shield were a steel cylinder, stiffened by a circular box-girder in rear of the hood, and having behind that a strong ring of cast iron carrying fourteen hydraulic rams. The cylinder extended behind the ram, forming a tail in which each tunnel-ring was built.

The iron lining for the 12-ft. tunnels, consisted of rings 18 in. in width. The tunnel was constructed with continuous longitudinal joints, machine faced, and dressed with a mixture of red lead and Stockholm tar before being erected. Joint-grooves were caulked with iron-rust cement, and both were grummetted where necessary. Blue-lias lime grouting was forced through the tapped holes provided in the iron, which were then screw-plugged. For regulating the driving of the shield, plumb bob lines for the tunnel centre, graduated side-rods drawn by the shield over fixed index-marks square to the centre line, a hanging plumb-line in the shield casting, and boning-rods behind the shield, had afforded every means of determining its position, and information for applying the necessary rams in driving, each ram working independently. Setting-out lines had been taken from a 15-ft. 6-in base transferred down the shaft by steel wires.

Tunnelling towards Waterloo had been begun at the shaft with 17 ft. of solid clay, and 34 ft. of total cover beneath the river-

bed. In April, 1900, the 8-ft. solid air-tight diaphragm-wall of brick in Portland-cement mortar, had been built across the tunnel and grouted under pressure, with the working air-lock and an emergency lock through it, and all necessary pipes. When the clay cover of the shield was only 5 ft. thick, the box heading in advance of the shield had been discontinued. Compressed air had then been applied with 5 ft. of clay cover, and at a depth of 18 ft. below the river-bed. As soon as the cutting edge reached within 2 or 3 ins. of the ballast, pockets of pugged clay had been made, close to each other, in advance of the face, forming a soft bed for the skin to enter, wherever the cutting edge would otherwise have encountered the ballast. As the amount of ballast-face increased, the handholes, separately excavated and filled, had formed a larger and larger portion of an annular bed in front, a close blanket against the shield-skin behind, and a lining to the ballast over the iron tunnel, securing a space for the grout around the iron, and an air-seal at the tail of the shield where it covered the last tunnel ring. The face had been timbered with close horizontal planking set against a thick plaster of pugged clay, and arranged by stretchers in two halves, across the face, held at first against the shield, and afterwards held by up-and-down soldiers, supported by round hollow steel struts passing through the shield, when driving the shield forward. The normal progress of the tunnel in ballast, had been three 18-in. rings per day. Three 8-hour gangs had been employed. The air-pressure used had been the exact equivalent of the hydraulic head in the river; varying, usually, during each tide, between 24 lbs. and 32 lbs. per sq. in.

Medical attendance had been provided for the workers, and every provision had been made for their care. Cases of compressed-air sickness had been infrequent, and the serious ones few. The amount of air at atmospheric pressure pumped through the tunnel, had varied between 30,000 cub. ft. and 200,000 cub. ft. per hour. The proportion of carbonic acid in the atmosphere in the working-space had varied between 0·06 per cent. and 0·10 per cent.

The East Tunnel had since been driven through the ballast by the use of the same shield, with a slight modification, to enable the miners to work conveniently while the face was kept altogether under cover of the hood. An average progress of over 5 ft. per working-day had been uniformly maintained, and the amount of air delivered had averaged only 100,000 cub. ft. per hour.—*Proceedings of the Institution of Civil Engineers.*

Edinburgh New Waterworks.

For the past seven years the Edinburgh and District Water Trust has been engaged in the undertaking of bringing in the waters of Talla from Peebleshire to supply the increasing needs of the area for which it caters. The works may take some three years more ere completion, and may cost one million sterling before the huge reservoir under construction in Talla Valley is completed, and the connection of some 32 miles made with the filter beds at Alnwick Hill, close to Edinburgh. This will add ten million gallons a day to the sixteen or seventeen million gallons at present received from the Pentland Springs and the Moorfoots, and will give at least 40 gallons per head for all purposes to a population of over 400,000. In one section of the aqueduct there has been some very difficult work caused by passing through loose sand and gravel, and by the presence of water. In a recent report by Mr. G. H. Hill, Manchester, it is stated that a considerable length of aqueduct is either in whinstone or sandstone, and that there had been no failure by subsidence in these sections. It was different in other sections, such as Auchencorth, where a failure had taken place. Therefore it was of importance that the complete concrete lining should closely follow the excavations so as to give support before any movement of material could take place. The capacity of Talla reservoir is estimated at 2,700 million gallons; the area covered will be 257 acres. The puddle trench forming the core of the embankment is 40 ft. wide at the base, and tapers to ten ft. at the top; the embankment will be 90 ft. high with a slope of four to one inside and three to one outside. Water from the reservoir passes in the aqueduct along the hillside to the new bridge over the Tweed, which it crosses in two large pipes, thence it rises by syphon to the opposite hillside and enters the tunnel. The Talla water will pass to the filters at Alnwick Hill for distribution.—*The Engineer, October 3, 1902.*

The New Bridge at Valence.

In an article dealing with bridges on the Rhone, M. A. Dumas gives an account of the new bridge which is now being erected across the river parallel with the existing suspension bridge. The new structure is to consist of four masonry arches of 164 ft. span, the thickness of the centre pier being 22 ft. and that of the intermediate piers 15 ft. 4 in., giving a total length of 708 ft. 8 in. between the abutments. At the crown of each span, for a width of about 98 ft., which corresponds with the space necessary

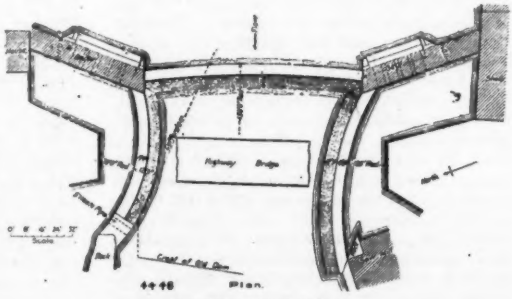
for navigation, the intrados forms the arc of a circle of 164 ft. radius; and beneath the roadway, which is 21 ft. 4 in. broad, it is joined to the face of the pier at each side by a parabolic arc giving the form of a basket handle. The footways, which are 5 ft. 3 in. wide, are supported by outer arch rings springing from the upstream and down-stream cutwaters of the piers, these rings being connected to the intrados by groining. The balustrades are in open stonework and rest upon a cornice supported by corbelling. In order that the greater part of the river should not be obstructed at one time, it was decided that the arches should be constructed in two series, and the central pier was given a greater thickness, so that it might form an abutment for the arches on either side. The pier foundations were formed by the aid of caissons sunk by compressed air down to the pliocene formation which is encountered at about 40 ft. below low-water level. Two piers are already built, as well as the abutment at the right-hand bank; the left-hand abutment has been partly finished, and the third pier remains to be built.—*Le Génie Civil, Oct. 25, 1902.*

Submerged Water-Pipes.

IN a paper read by Mr. A. L. Holmes before the Central States Waterworks Association, it is said that in the larger cities along navigable waters, care must be taken that submerged pipe lines—as largely adopted in the United States—are beyond the reach of keels or propellers, and that the pipes are protected at the docks and landings. The only safe way for laying pressure pipes across navigable streams is to place them in a trench, well below the bottom of the river. In some places the pipe is laid on the mud, and then by aid of a sand pump the line is gradually worked down. At Michigan City, Ind., a 20-in. force main across the harbour was lowered from a depth of 16 ft. 5 ins. to a depth of 20 ft. by the use of a sand pump, and without any damage being done. This pipe was 160 ft. long, and was fitted with five ball joints, and, together with 1,200 ft. of other pipe on shore, showed a leakage under 100 lbs. of water pressure of only 168 gals. in 24 hours. A 16-in. riveted pipe across the stream at Hammond, Ind., was lowered in this way and by the use of a water jet, and was perfectly tight when down. Of course this way of doing the work is not advocated where it is practicable to make and maintain a trench otherwise, but some streams are so swift and carry so much fine sand or silt that the trench would fill as fast as dug. The writer's preference for submerged pipe is cast-iron socket and spigot, with lead joints, and at every 36 to 48 ft. a flexible joint. After describing the details connected with this class of work, the paper concludes with some useful remarks on the management of such a system.—*The Engineering Record, Oct. 4, 1902.*

A Concrete Power Dam at Middle Falls, N.Y.

THIS dam was undertaken to replace a timber dam that leaked badly, and was designed by Mr. Henry Floy of New York City. The water is diverted to each side of the stream for a pulp mill on one bank and various mills and an electric lighting and power station on the other, the owner of the latter, the Consolidated Electric Company, controlling the entire water-power. Two waterways had thus to be maintained, and a dam was built across the stream with gate structures or abutments at each end, with a rollway in the centre 114 ft. long, and two wing dams running down-stream from each end of the rollway portion separating each waterway from the stream proper. The wing dams are somewhat similar to the rollway portion of the main dam, and are designed to afford 165 ft. additional rollway in times of high water. As shown in the accompanying plan of the dam, the abutments are not in a straight line with the main rollway section, but all parts, including the wing dams, are arranged to have a mutual bracing effect. The main dam is curved upstream on a 450-ft. radius. The wing dams differ from the main rollway section in that there is no inclined approach to the crest, as racks in front of the gates keep out large floating bodies, such as ice and logs. The area of the cross-section of the dam is about 90 sq.



CONCRETE POWER DAM.

ft., so that allowing 145 pounds per cu. ft. for the concrete, the weight of the dam is 6·5 tons per lineal foot. The structure is entirely of concrete mixed in the proportion of one part Portland Cement, three parts sand, and four parts gravel. One of the difficulties encountered in the work was in providing sufficient waterway, and which indeed partly accounts for the curvature of the wing dams. Between the old dam (the position of which is indicated on the plan) and the new dam are located the abutments of a highway bridge. The flow of diverted water had, on both sides of the stream, to be taken around these abutments, and to secure the maximum possible area, the rock was cut away as far as safe around the abutment foundations.—*The Engineering Record, Oct. 4, 1902.*

POWER.

Recent Oil Motors.

In a paper read last month before the Institution of Mechanical Engineers, Capt. Longridge, M.I.Mech.E., brings forward the present technique of motor car manufacture with the view of advancing for discussion debateable points in the principles of construction embodied in oil motor cars of 1902. The following are the chief points raised and the opinions expressed by the author: *Types of motors.*—Petrol-car engines are generally of the vertical single-acting Otto type, but in America the tendency is to adopt the horizontal type, an example likely to be followed in Europe. The author holds that neither type is going to stay, and believes that the ultimate evolution will be the "impulse every revolution" engine, a form of which he has recently patented. *Material and methods of manufacture.*—Existing designs of motors are said to be calculated to give trouble in the foundry and workshop. The author favours the substitution of steel tubes for cast-iron cylinders, the tubes to be screwed into cast-steel or cast-iron heads, and the use of a light-rolled metal water-jacket. In using steel cylinders cast-iron piston-rings might be retained. *Engine details.*—Mechanical valves are advocated; the author considers the valve head should be of nickel-steel, and that port passages should be avoided, the inlet and outlet valves being placed on the head of the combustion chamber. *Valve area.*—There is a marked and praiseworthy tendency towards increased areas, but more complete formulæ are still wanted for calculations. *Carburettors.* — Aspiration and positive-feed carburettors are described, and several important points are raised in connection with the problem of carburation. *The fuel.*—On this important part of the subject the author says it is astonishing that petrol should have been so long in use and yet so little known about it. Consequently, as far as carburation is concerned, makers are working more or less in the dark. *Ignition.*—Electric ignition is the only method considered in detail, and existing systems admit of improvement in respect of automatic timing and automatic consumption of current. *Systems of governing.*—Four existing systems are described, the best being one which retains the full discharge of air and reduces the amount of petrol. *Charge expansion.*—Several ingenious systems are described and discussed. *Cylinder cooling.*—Air-cooling, except as a supplementary aid, is said to be impracticable, or in any case vastly inferior to water-cooling, for which several types of apparatus are mentioned. *Silencers.*—The influence of these on engine power is emphasised, and the question is raised as to what is the proper ratio between the silencer and the cylinder. *Communication of motor power to the car.*—The methods adopted in the Peache and the Westinghouse steam-engines are cited as instances which motor manufacturers might well copy in the arrangement of cranks and crank-shafts. The author does not agree with the use of mild steel for crank-shafts as advocated in this country. He considers a tensile strength of 40 to 50 tons far more suitable. With regard to fly-wheels, it is said that vibration may be eliminated by the employment of two fly-wheels revolving in opposite directions. With regard to axles, the author says it is a strange thing that no English firm appears capable of turning out motor-car axles of quality and accuracy equal to the production of French and Belgian firms. Most leading firms import largely from foreign makers. The superiority in question seems to depend upon a method of hammering which is more or less a lost art in England. The employment of weldless steel tube or hollow-bored axles, which is the latest development, ought to suit British makers, and, if successful, British-made axles ought to be found on every car. The same remark as to the superiority of the foreign-made article applies to motor-car springs. The paper concludes with an appeal to the Institution that the scope of the Gas-Engine Research Committee may be extended to the investigation of the problems surrounding and impeding the progress of the petrol engine.—*Proc. I. Mech. E., Oct., 1902.*

Progress in Gas-Engines.

In a recent paper, Mr. H. A. Humphrey, M.I.Mech.E., traces the development of large gas-engines during the last few years, stating that engines of 1,200 h.p. and 1,500 h.p. are already working, and others of 2,000 h.p. to 4,000 h.p. are being constructed. Since 1900 Messrs. Crossley Bros. have received orders for 28 large engines with a total of 8,300 h.p., or an average of 296 h.p. per engine; the Premier Gas-Engine Co. have contracted to build 23 engines with a total of 9,300 h.p., giving an average of 404 h.p. each, and of the 17,600 h.p. thus provided, 12,500 h.p. is for driving dynamos. On the Continent, omitting all engines below 200 h.p., Messrs. Körting Bros. have made, or have under construction, 32 gas-engines with a total of 44,500 h.p., averaging 1,390 h.p. per engine; the John Cockerill Company come next with 59 engines, having an aggregate of 32,930, and an average of 558 h.p.; the Gazmotoren Fabrik Deutz takes the third place with 51 engines developing collectively 20,665 h.p.; and are followed by the Deutsche Kraftgas Gesellschaft with 28 engines giving 16,900 h.p. A classified list of these and other large gas-engines gives the remarkable total of 327 engines capable of supplying 181,605 h.p. In America, the De la Vergue Refrigerating Machine Co. have on order 16 2,000 b.h.p. gas-engines of the Körting type; the Lakawanna Steel Works have ordered five 1,000 b.h.p. gas-engines for driving dynamos; the Snow Steam-pump Works have already made six 1,000 h.p. gas-engines, and are now finishing two gas-engine gas-compressors of 4,000 h.p. each; the Westinghouse Machine Co. have made gas-engines of 1,500 h.p., and are prepared to build up to 3,000 h.p. In dealing with the design of modern gas-engines, the author notes several points of importance. The general tendency, he says, is to make all parts very rigid; the Premier Company set the example of water-cooling the piston and valves, which was followed by the Cockerill Company; the breech-end casting of the cylinder has been much improved; valves are almost entirely of the mushroom type operated by cams; ignition is now performed by the electric spark in one of three recognised methods; and improved methods of governing are being adopted by all the leading makers. The author then proceeds to show the lines on which the gas-engine of the future will be developed, and believes that British manufacturers will not be behindhand in promoting the development of the large gas-engine, which he believes to be *the engine* of the century.—*Proc. Brit. Assn., 1902.*

Electrically-driven Machinery.

Mr. Frank Broadbent, M.I.E.E., points out the economy and advantages to be derived from the electrical driving of machinery. After giving some notes upon the savings effected by motor driving, he very fairly says that the immense savings shown therein are in some cases due as much to the shockingly bad mechanical systems replaced as to the undoubted excellence of electrical methods. In old works shafting and belting often absorb from 50 to 80 per cent. of the power generated, and it does not take much to beat a system of that nature. Even if efficient, a mechanical system of driving is inelastic; and as machine after machine is added to a works, shafts, bearings, and hangers become so strained and twisted that the author wonders, not that they absorb so much power, but that they stand it at all. An electric system, on the other hand, is perfectly elastic; motors can be added without affecting efficiency, machines can be put in any desired positions, and perfect control is possible. An example is given showing the necessity of applying electric driving intelligently. In this the motor merely replaced a steam engine, and there were still such heavy losses by the transmission of power through shafting that, while the power usefully employed was only 10 kilo-watts, the amount wasted was 7 kilo-watts. So it cost the proprietors £182 a-year for wasted energy. "And this, forsooth," the writer says, "is called electrical engineering." He adds that electricity generated by steam-power must necessarily be dearer at the generator than the steam-power itself. It is

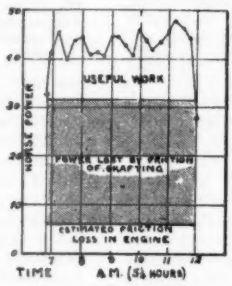


FIG. 1.

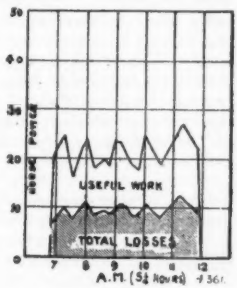


FIG. 2.

ELECTRICALLY DRIVEN MACHINERY.

only in the method of transmission and application that electricity scores; only by getting it right up to the tool or machine, avoiding all unnecessary losses in transit, can the highest economy be secured, and every other method of driving be commercially beaten. Fig. 1 is an interesting curve, showing the relation between the useful and wasted work in a factory tested by Mr. Crocker. Here the total losses vary from 65 to 80 per cent. Fig. 2 shows the approximate results that a change to electric driving would effect, assuming electricity to be generated at the works by means of a coupled plant. Here it is seen that the engine and boiler power need be only 30 h.p., instead of 50 h.p., and that, whilst the total losses in engine, dynamo, cables, and motors are under 35 per cent. at full load, the loss is not a practically constant quantity, as in the case of mechanical transmission, but varies with the load. At no load the motor and cable losses disappear entirely, and both engine and dynamo losses are reduced somewhat. The article from which these notes are taken concludes with some hints concerning the most efficient system of control, the best type of motor, and the application of fly-wheels. — *The Electrical Review, September 12, 1902.*

Relays and Governors.

FOR moving the heavy link motions of marine and other forms of steam-engine, Mr. Arthur Rigg says, the relay performs a most serviceable function, and the same form of device serves as a basis of every description of steering gear, whether driven by steam, water pressure, or compressed air. The relay system is peculiarly suitable for governing steam engines or turbines wherever heavy valves or sluices have to be moved and regulated through the feeble powers of a governor. The simplest way in which a governor employs a relay is the old-fashioned device whereby its variations in speed raise or lower a claw, or friction clutch, which is put in action whenever the governor balls pass beyond the free limit of their range. There is always an element of uncertainty in the action of such governors as admit pressure to the cylinder of a relay; they are liable to run from top to bottom of their range, and the speed of the motor suffers correspondingly. For steering large vessels a steam steering-gear is essential, and the first known example of a successful steering gear is that which was designed for the Great Eastern steamship. This arrangement is fully described in the Proceedings of the Institution of Mechanical Engineers for the year 1897. Another method for working such a relay by steam or water pressure as described by Mr. Rigg, is most efficient and entirely removes all difficulty concerning "hunting." The most positive form of mechanical relay is that which makes use of water or other liquid pressure for transmitting whatever movement may be desired, or for moving any load for which provision has to be made. An illustration is given by the writer of a relay constructed on this positive hydraulic system. The action of a relay and the "hunting" of a governor may seem a double subject, but Mr. Rigg says the combination of governors and relays is so essential in many cases that it is well to combine the main considerations of the points to be observed in order to secure the proper performance of both.—*The Engineer, Oct. 17, 1902.*

Single-Phase Alternators on Polyphase Circuits.

AN experiment of considerable theoretical and practical interest, incidentally illustrating the elasticity of the polyphase current system, was recently tried successfully at Phœnix, Arizona. This experiment was a practical demonstration of the possibility of using single-phase alternators as the source of energy for supplying polyphase currents, both two-phase and three-phase, and also for supplying direct current to a transmission and distribution system. The experiment was conducted, on April 7th, 1902, by Mr. C. O. Mailloux, assisted by Mr. D. W. Beldon, the electrical engineer of the Phœnix Light and Fuel Company, of Phœnix, using the machinery and facilities of the old steam station and of the new transformer sub-station of that company. The system adopted is three-phase transmission at 22,500 volts at the transformer station, where there are two sets of lowering transformers, including those for the lighting and power current service. The company purposes to furnish alternating current for both lighting and power from two-phase 2,200 volts feeder lines, and direct current for power only at 500–550 volts, the power current system to be supplemented by a storage battery. At the old steam station there are three single-phase monocyclic alternators, the intention being to discard this station after the completion of two new water-power stations. One of the latter had already been equipped, but as the second was not likely to be completed in time for the low-water season, it became necessary to consider the best ways of utilising the existing steam plant as a supplemental source of power capable of operating in conjunction with the first water-power station, and even of replacing it altogether in case of emergency. There were two problems

to be considered: (1) That of running the incandescent lights partly or wholly from the steam-driven, single-phase alternators; and (2) that of generating direct current for the power circuit, and for charging the battery. The first problem was dealt with by coupling up the single-phase alternators with the two-phase bus bars in the sub-station, the alternators being brought to synchronous speed by regulation of the engines. No difficulty was found in making the alternators keep in step, or in making them carry a proportion of the total load. It was also found that they could be utilised in balancing the two phases, in case they were unequal in potential difference, owing to unequal loads. The first problem, therefore, being solved by these experiments, the second problem was then taken into consideration. After careful consideration of all the reactions involved, the writer decided upon an experiment which fully justified his anticipations. The generators, having been connected with the transformers, and excited so as to give the full line voltage on the transmission line, the rotary converter was then started in the regular way. This having been done, two of the single-phase alternators were coupled in succession to the feeder bus-bars, one to each phase; a Lincoln synchroniser connected as a phase-indicating device, showed that a perfect quarter-phase relation was being maintained. After all adjustments had been completed, the line switches were then pulled open, thereby disconnecting the transmission line, and shutting off all electric energy supplied from the water-power station. The index of the synchroniser remained all the time at a point 90 degs. from the position of synchronisation, thus showing that the two-phase relation was maintained as perfectly as when the rotary converter was run with current supplied from the transmission line. The external load was then varied by opening and closing the feeder line switches at the lighting switchboard. The maximum load put on was equivalent to more than three-quarters of the full current capacity of each alternator: the load being composed almost entirely of incandescent lights the power factor was, of course, somewhat high. After continuing the experiment for about ten minutes, the A. C. switches of the rotary converter were opened, and the alternators were immediately disconnected from the feeder bus-bar lines, the synchroniser having shown that the quarter-phase relation was lost at the same instant that the rotary converter was disconne ted. The experiment was repeated with slight variations two or three times, and each time with perfect success. There were no facilities for imposing a direct-current load on the converter in addition to the load resulting from its operation as a phasing device for the two alternators. There is no reason to doubt, however, that a direct-current load could have been placed upon the rotary converter up to the full generating capacity of the two single-phase alternators serving as the source of current supplying the experiment. The experiment may, therefore, be taken to be a sufficient demonstration of the possibility of using single-phase alternators to produce two-phase current, three-phase current and direct current, with an arrangement and under conditions such as those described. *Proc. Am. Institute of Electrical Engineers, June, 1902.*

The Up-Keep of Direct-Current Motors.

REFERRING to the most serious and frequent causes of trouble to which direct-current motors are liable, Mr. Alfred H. Mayes says that costly repairs and inconvenient stoppages might be largely avoided if users would see that such machines were always kept in proper order. Overheating of the armature windings, which is mentioned as a prolific source of trouble, can be prevented by the provision of a suitable fuse of "known capacity." The writer mentions the principal factors governing the carrying capacity of a fuse, and says it is not sufficient to rely upon cross-section and the nature of the metal, adding that, given careful attention to essential requirements, the actual time and current limit of a fuse should be a known and definite quantity, and that the application of a tested fuse of this class to every motor would relegate to the past the costly mishap called a "burn-out." With regard to severance of the field windings, the writer thinks that experience has shown dampness to be by far the most serious enemy with which field coils have to contend, and to be responsible for more breakdowns than any other cause. If the motor cannot be fixed in a dry situation, the whole of the field coils should be treated with hot paraffin wax, preferably in the process of manufacture. Another precaution is to see that the starting switch connections are such that the field coils are not subjected to excessive strain owing to induced e.m.f. when the circuit is opened. Owing to the high speed at which the average electric motor runs, the question of oiling the bearings becomes a point of the greatest importance; and this should be done at regular and stated times, the oil used being of a rather light character. Most high-class motors are now guaranteed by the makers

to run sparklessly at all loads, but this result may easily be negatived by careless setting of the brushes. Brush blocks must bear fairly and evenly upon the commutator, and also be so placed that the positive and negative brushes are at opposite points of its circumference. After running for some time the brushes will naturally become worn to a shape corresponding with the curve and plane of the commutator, and their setting should therefore never be disturbed until wear renders it requisite to do so. Sparking is frequently caused by the brush blocks being insufficiently pressed into contact with the commutator by the adjustable spring gear provided for the purpose, as in many forms of gear the spring has to overcome the tendency to bad contact caused by the weight of the brush and brush-holder, in addition to the usual vibrations. Lubrication of the commutator in any form the writer considers to be inadvisable, for it amounts to placing a film of non-conducting matter between the brush block and the commutator, where a perfect electrical connection should exist. Turning to accessories, the writer says that the switch contacts will need attention from time to time, owing to the deterioration caused by the sparking, which cannot be entirely avoided, but can, however, be reduced to a minimum by careful design and construction, which are too often wanting in present-day starting switches. The contacts must be constantly cleaned to prevent the accumulation of fused matter, and it is especially necessary to keep the contacts smooth and clean in the case of automatic switches, as otherwise the friction caused by their rough condition may prove too great for the power of the pull-off spring, in which case the contact arm will come to rest before all the resistance is cut out; and this, if unobserved, may lead to the over-heating and destruction of the resistance coils. Not only the contacts but the contact-maker fitted to the switch-arm must be kept in good condition, and care must be taken that the electrical connection with the switch-arm is sufficient to carry the current, in order that no local heating may occur. When overload preventers and circuit-breakers are employed, it is absolutely essential that they shall be carefully tested at frequent intervals, and the rubbing surfaces and moving parts be kept perfectly clean and in free working order, as a very slight amount of undue friction, caused by a gradual accumulation of oil and dust, will materially increase the current which must pass before they will exercise their function of opening the circuit. In connection with such devices the writer again urges the addition of a reliable fuse, as one failure to act may prove an expensive business.—*Electrical Review, Sept. 12, 1902.*

Commercial Aspect of the Steam Turbine.

AT the Detroit Convention of the American Street Railway Association, Mr. Edward H. Sniffin presented a paper entitled "The Steam Turbine; its Commercial Aspect," which gave information in detail of turbine plants now in operation, and discussed the cost of turbine plants and operation as contrasted with ordinary steam plants. In units as small as 400 kilowatts, a result may be obtained of 14·47 lbs. of steam per b.h.p. per hour, corresponding to less than 13¾ lbs. per i.h.p. As the units become larger, the turbine is then brought into comparison with the best steam-engine practice, where it still preserves its uniform efficiency, and where its practical advantages are no less evident. In a recent instance, a result of 11·7 lbs. of steam per e.h.p. per hour was guaranteed on a turbine of 750 k.w. capacity, corresponding to about 10·17 lbs. per indicated h.p., which, though the size is moderate, is, perhaps, within the ability of but few engines of any size or type that have ever been built. Curves were given showing that the turbine requires about 80 per cent. of the space needed for the vertical engine, and not over 40 per cent. of that wanted for the horizontal. Another set of curves showed the cubic yards of foundation material required, which was stated to be a more exact and striking comparison. The turbine would appear more advantageously still, if the actual foundations needed for stability had been computed. But even without this the foundation volumes are shown in the following proportions: turbine 1, vertical engine 9, horizontal engine 15. Several actual cases were given to show the saving in cost. A plant was recently laid out to contain three 1,000 k.w. units, with vertical cross-compound Corliss engines. Subsequently three more 1,000 k.w. units were contracted for, steam turbines being adopted. It was found that the turbine saved 900 square feet of engine-room floor space and about 38,000 cubic feet. Had the whole plant been originally designed for turbines, the saving of space would have been double these amounts, and the cost of land, building and foundations would have been reduced about 50,000 dols. In an electric railroad plant in Ohio it was found that the engine-room space planned for additional generators with an output of 2,000 k.w. would be sufficient for 5,000 k.w. by the adoption of turbines, and the boiler-plant extension would be reduced about one-third. One other case,

of perhaps greater interest, was that of a plant of 8,100-k.w. capacity, laid out on modern lines. There was no space for additional engine-power, and any increase would require building costly extension. It was shown that without going beyond the present building, and without disturbing the existing machinery, the plant might be doubled in capacity by installing turbines in space available below the engine-room, and by adding another deck of boilers. This arrangement would effect a reduction of over 3 dols. per kilowatt per annum in the present interest charge.—*Electrical World and Engineer, Oct. 18, 1902.*

Feed Waters and their Action on Boilers.

It is passing strange, says Mr. Clifford A. Bowen, the amount of ignorance displayed by the average engineer with regard to the proper treatment of his boiler plant. Everything that can be seen and heard is rigidly looked after, but the unseen is never thought about. Among the principal impurities of water dealt with by the writer are:—bases: soda, ammonia, lime, magnesia, iron; acids: sulphuric, carbonic, and nitric acids; and organic matter. Carbonic acid has a most pernicious effect in dissolving and absorbing impurities which would otherwise be only slightly soluble in water. When heat is applied the carbonic acid gas flies off, and dissolved mineral salts are precipitated as scale. In water-tube boilers the deposit comes into contact with the hot tubes, more so than with a Lancashire boiler, and soon coats the tubes with a layer of scale. Should oily matter be present, the plates become coated with a greasy film, upon which the precipitate settles and becomes baked into a hard scale. The only economical way of effecting the removal of calcium carbonate is by treating the water with lime or lime-water in settling tanks of some kind. In a boiler fed with water containing organic matter, the author says that scale $\frac{1}{32}$-in. thick is decidedly beneficial, preventing free acids from causing pitting and corrosion; but where water is drawn from wells where the strata are chalk all scale should be removed as often as possible. Sulphate of lime is most objectionable in a boiler on account of the hardness of its deposit, which is most difficult to remove, adhering to the plates as a scale resembling stone. In places where the plant is neglected, sulphate of lime is precipitated on the plates and tubes, cementing the carbonate of lime into a hard, stony scale. The addition of soda solution converts sulphate of lime into carbonate of lime, while sulphate of soda remains in solution. The addition of soda also tends to neutralise acids liberated by the decomposition of chlorides and sulphates of magnesia.—*The Electrical Review, Oct. 3, 1902.*

Electricity in Cotton Mills.

In December, 1897, Mr. Smith Whaley presented (vol. xix., p. 467) a paper on this subject before the American Society of Mechanical Engineers. Much question was then raised on the efficiency problem of the paper, and the consensus of the criticisms was a question as to whether it was economical to install a cotton mill in the manner described. A second paper read by the author this year contains a further discussion as to the economy of electrical transmission, based upon tests conducted at the recently equipped Olympia Cotton Mills in Columbia, S.C. The results of the investigations are given in a series of tables and in graphic diagrams which are very interesting and useful. It should be explained that the nature of the service—namely, the alternating current with induction motors—is quite different in its action from the direct current or similar conditions in a belt or rope-driven mill. The generators running in parallel are always in step and cannot change; consequently it is impossible for one part of the plant to speed up or down according to variations of the work. As the motors all run at the relative speeds compared to the generator for which they were designed, an absolutely steady speed is maintained, and the entire tendency to acceleration or retardation is absorbed in the machines themselves, ensuring an absolutely uniform application of power throughout the plant. The sixty tests recorded by the author give the following average results:

	Mill Losses.	Friction Losses.	Total Losses.
Generator A	+ 14·22	+ 2·91	17·13
B	+ 14·22	− 2·78	11·44

As a fact, the friction losses are practically constant, and the apparent difference is merely a reduction of the mill friction due to generator action in the motors. The only possible measurement of this is by the indicator diagrams, the results from which are given in the tables. From these data it appears that the friction losses in the Olympia plant are far less than in any other method of driving cotton mills, with an apparent efficiency of over 82 per cent. net, or with the average diminution of total friction, the average friction does not exceed 15 per cent. It is to be hoped that this paper will lead to more investigation on this most important subject.—*Proc. Am. Soc. Mech. E., May, 1902.*

TRACTION.

High-Capacity Wagons.

TRIALS now being conducted on the North-Eastern Railway in the use of high-capacity mineral wagons are to be extended to the use of some 40-ton wagons. The steps taken by the North-Eastern Company for the purpose of determining the most practicable and economical type of wagon are: (1) The building of 15 and 20-ton wooden wagons; (2) The building of twelve 32-ton Sheffield and Twinberrow wagons; (3) The building of fifty 40-ton Sheffield and Twinberrow wagons, and a number of 40-ton pressed-steel wagons. The wagons referred to in the first two headings have been running for some time; one or two of the 40-ton wagons are already running, and others are being introduced on the system. When first introduced, the 40-ton wagons were made in two sections, each with a hopper floor some 2 ft. square, and divided by a partition the full height of the wagon. The height of the partition is now reduced to between 12 in. and 18 in., the reduction enabling the wagon to be loaded from one end to the other with greater facility. Other improvements have also been made relating chiefly to the gear for manipulating the sliding doors of the hoppers, and to the substitution of oval spring buffers for the previous type used. Westinghouse draught-gear is applied and so arranged that the buffers can be taken off, and an automatic coupling used in place of the central coupling hook. Having regard to the fact that one new wagon takes the place of four of 10-ton capacity, the labour of manipulation is reduced to one-eighth, and the saving in haulage of trucks over the shoots is in a corresponding ratio. The details of construction of the new wagon are well worthy of consideration, but we cannot describe them in this brief abstract. Messrs. Sheffield and Twinberrow claim the following advantages for the high-capacity wagon: The maximum proportion of "paying" load carried by 10-ton wagons is 61 per cent. of the gross load, but the employment of high-capacity wagons will enable the proportion to be increased to 75 per cent.; when the traffic can be dealt with in full train-loads, an increase of 21 per cent. in gross receipts may be secured, while the train mileage and working expenses remain constant, or if the volume of traffic is the same, the train mileage may be reduced by 17 per cent.; the freight load per running foot may be increased from 0·52 tons to 0·84 tons, and this is equivalent to increasing the effective capacity of sidings by 62 per cent.; the total saving in repairs will be not less than 50 per cent. An economy of 15 per cent. in the annual cost of power and maintenance, and of 50 per cent. in wagon repairs, would save, in connection with the mineral traffic of the United Kingdom, upwards of 2⅛ million pounds, equivalent to a capital value of 50 million pounds. It is thought by the writer that neither the railway manager nor the private wagon-owner is likely to accept these views in their entirety.—*The Iron and Coal Trades Review, Oct. 3, 1902.*

The Tyneside Tramways.

THE districts through which the lines of the Tyneside Tramways & Tramroads Co. pass are of great industrial importance, as some of the principal shipbuilding yards and engine works in the country are situated therein. The lines now completed pass through Gosforth, Wallsend, and Wellington Quay to North Shields, and when the Newcastle Corporation have completed the extension in Walker, which is now in hand, direct tramway communication will be afforded along the whole bank of the Tyne, from Newcastle to North Shields. The distinctive term "tramroad" is applied to a tramway laid on ground other than public roads, and in the Tyneside district the tramroads laid on ground owned by the company will be used for traffic at higher speeds than those permitted on ordinary tramways. From Gosforth to Wallsend the new tramroad follows the route of an old colliery wagon-way formerly used for conveying coal from Coxlodge Pit to the river. On this road a special form of grooved girder rail is adopted, having a check ⅜ in. higher than the tread, to give greater security at the high speeds permissible at this portion of the system. A good portion on the section is single track, but there are frequent passing places, and as these are situated near public roads where speed would have to be reduced in any event, the cars are able to make very good running. Between Wallsend and North Shields and in Gosforth the tramway is of double track in many places. The gauge is 4 ft. 8½ ins., the same as that of the Newcastle Corporation lines, and on ordinary lines a 95-lb. girder type rail is adopted, with soleplates at the joints in addition to fishplates. The whole of the track and overhead equipment has been constructed by Messrs. Dick, Kerr & Co., all special work being of Messrs. Hadfield's manufacture, their manganese steel being used throughout. At present the rolling stock consists of four bogie cars each carrying 112 passengers, and 14 single-truck cars each having a capacity for 80 passengers. All cars are fitted with Tidswell's life-guards, and both hand and electric brakes, the latter being of the

Kervell magnetic type. The car contract was carried out by The British Westinghouse Electric Manufacturing Co., the car bodies having been supplied by Messrs. G. F. Milnes. Power for working the lines is derived from the Wallsend works of the Newcastle Electric Supply Company, but the Tynemouth Corporation will supply that portion of the line within their boundary. It is expected that the gap at present existing between the systems of the company and that of the Newcastle Corporation will be filled up within 12 months.—*The Electrical Engineer, October 3, 1902.*

Oiled Roads.

AN experiment with petroleum oil upon a portion of the London and Southampton road, between Farnborough and Aldershot, was commenced on Sept. 27. This is a thoroughfare much frequented by motorists and cyclists, and is near the great camp of the First Army Corps. Two thousand five hundred gallons of Texas heavy oil were supplied for the purpose by the proprietors of the *County Gentleman*, and the oil was placed upon the road under the immediate supervision of the county surveyor of Hampshire. The oil was laid upon three-quarters of a mile of road, commencing at the thirty-second milestone from London. Several dressings were given, the oil being first distributed by means of a watering-cart, and subsequently, in order to secure an even distribution, the men went over the length with large watering-cans. The oil soaked quickly into the road and left the surface well knit and firm. The treatment was immediately successful in preventing dust. On Sunday a large number of motor-cars passed along the road; on the oiled portion they raised not a speck, but immediately that was passed they disappeared in a whirlwind of dust. It was feared that the smell from the oil would be found objectionable, but the odour was much less than was anticipated, and while objected to by some people was considered by others to be not unpleasant It is rapidly passing away.—*The Car, October 1, 1902.*

The Quick Renewal of Permanent Way.

THERE are three methods of relaying permanent way—one being, first, to replace the old materials with new materials, piece by piece, lifting out the old rails and putting the new rails into the old chairs as the old rails are removed. The next step after the renewal of the rails would be to replace the old chairs and sleepers, one by one, with new sleepers and new chairs. This method will probably be more expensive in the long run than the other alternatives, and will occupy far more time. An alternative to this is, secondly, the putting together of the new material before removing the old line, and this can be done in two different ways: (*a*) the new track can be put together parallel to and outside the old track, an expeditious way of executing the work, providing the embankments and cuttings are wide enough and sufficiently free from obstruction to allow of this being done; or (*b*) the near line can be interlaced with the old, leaving the new rails about a foot away from the old rails—a system which presents the greatest advantages when the chairs have to be attached to the sleepers on the ground. In either case the new line is finally slewed into position when the old line is removed. The other alternative is, thirdly, entirely to clear away the old line, to prepare again the formation or the bed for the sleepers, and then to relay the permanent way in the manner that would be adopted for new lines not yet opened for traffic—a method preferable for general adoption in all cases where it is practicable, and one that will eventually be the quickest and most economical. The method of relaying by Sunday work (in preference by single-line working) is the one most favoured on English railways, where trains are so frequent and so heavy, and where there are also so many connections to make with other companies' trains. The road is usually partly denuded of its ballast in the two or three days preceding the actual Sunday relaying work, and as the line is not altogether safe for two or three days after the actual relaying has been done, it is the usual practice to slacken trains over the railway both before and after the work is done for two, three or four days.—*The Engineer, Oct. 17, 1902.*

A fast Run on the G.C.R.

IT is within the knowledge of everyone interested in railway practice that the express services on the Great Central Railway have been greatly improved in point of speed since the accession of Mr. Sam Fay to the management of that Company. A run little less than remarkable and worth placing on record was recently achieved by Engine No. 855, which was one of those constructed by Mr. Harry Pollitt and is of the four-coupled bogie type with Belpaire firebox. This engine, which took the 2.15 up Manchester-London express, was attached at Leicester, the train consisting of eleven coaches, including one dining-car, leaving at 4.40 p.m. It ran the 65 miles from that place to Quainton Road, where the junction with the Metropolitan rails is effected, in 64¾ minutes, traversing the last 47 miles of this

section in the remarkable time of 41 minutes, which is an average of 68·7 miles per hour. Forcing this engine, however, did not appear to agree with the boiler, as the lagging, consisting of wood and felt, fired during the journey, resulting in the train having to be pulled up after Quainton Road had been passed, for the fire to be extinguished. It is difficult to understand why this old form of lagging is still adhered to, as the adoption of asbestos coverings would entirely eliminate the possibility of such a thing happening.

TOOLS.

Tools and Tool Steel.

In a report presented at the recent convention of the National Railroad Master Blacksmiths' Association, the following observations are to be found. Crucible or carbon steel is recommended in these qualities: select grade for lathe, planer, slotter, screw-cutting dies, etc.; second grade for chipping chisels, hammers, etc., that have to withstand shock; and third grade for hot punches, fullers, flatters, sets, etc. Here are a few simple rules on which nearly all are agreed, and which must be followed to ensure success:—Select a good steel for the purpose for which the tool is intended; have a clean fire, a deep body of fuel to prevent the cold blast from getting through; heat slowly and thoroughly; use judgment in forging, turning the steel over and upside down frequently; see that your anvil is nice and smooth, and never try to temper on the same heat for forging unless it be a track pick. For machine tools, after forging to shape, lay aside till cold, then reheat as above in a clean, deep, bright fire slowly and thoroughly, not any higher than is necessary to get the requisite hardness; then dip in your cooling bath. For lathes, planers, etc., we do not think it is good policy to draw temper; a little practice with dipping will be found as satisfactory, or more so. We all know colour stands for nothing unless the necessary hardness is first placed there, and also that the eye has its limit, and cannot register the degree of heat. Now we want a good heating furnace for steel, one that is slow and steady, with a pyrometer to register the degrees of heat. Raise your furnace until it reaches the degree of heat wanted, hold there until you are certain your steel is thoroughly heated through, immerse in your cooling liquid, and your job is completed. It will be noticed there is no guesswork about this. The eye may be deceived, but you are governed by laws that are absolute, and every day, whether dull or bright, the results will be exactly the same.—*The Mechanical World, October 10, 1902.*

ENGINEERING ECONOMICS AND MISCELLANEOUS.

Ether-Air Gas.

Occasional use has been made for some years of ether-air gas in connection with optical lantern work in places where oil light was of insufficient power, and an apparatus has been devised which should have the effect of further extending the application of air saturated with ether gas. A new carburetter has been invented which is claimed to be specially suitable for ether. The absorbent material is the fibre of a palm-like tree, which has an apparent specific gravity of from 0·114 to 0·122, and is so extremely porous that it will take up nine times its weight of ether, all of which is subsequently evaporated into gas. Ether itself burns with a luminous, or even smoky flame, but when diluted with air its vapour, as in ether-air gas, gives a blue flame, and for purposes of illumination requires either a mantle or the addition of benzol-vapour. According to Langlois, incandescent ether-air gas gives a light of 1 Carcel-hour (about 9·5 candles) for every 6·7 grammes of ether burned; while the material will bear cooling to 21 degs. Fahr. without any of the ether condensing out and without suffering any diminution in illuminating power. By carburetting ether-air gas with 40 or 50 grammes of benzol per cubic metre, a product resembling oil-gas in stability can be prepared. It is stated that carburetted ether-air gas is almost twice as expensive as oil gas; but it has an advantage over the latter in the simplicity of the plant required and in the rapidity with which a small installation can be erected. It may be noted that the introduction of ether-air gas renders ambiguous the term "air-gas" as applied to air carburetted with petroleum spirit; and the latter product should now be called "petroleum-air gas," or by some equivalent title—*The Engineer, Sept. 5, 1902.*

Unit Cost of Work.

A discussion on this subject was opened at the last convention of the American Society of Civil Engineers by Mr. Samuel Whinery. Two questions were raised, the first relating to the possibility, and the second to the desirability of account keeping intended to disclose the unit cost of work. The first of these has been answered in the affirmative by practical

experience, and the author says it may be confidently asserted that, with the same amount of care usual and necessary in a first-class mercantile establishment, it is possible to determine with accuracy the unit cost of any engineering work. With regard to the second question, it is pointed out that a knowledge of the unit cost of work is of value in many ways, and accounts which enable us to ascertain it are therefore desirable. To the engineer engaged in designing modern work, the important problem is how to accomplish the object sought with the least expenditure of money. The engineer, therefore, finds it important to accumulate the largest possible fund of cost prices. To the contractor or the manufacturer, the question of desirability is synonymous with the question, "Will it pay?" and among the more enterprising and intelligent there can be but one answer. The question of success or failure in these times of sharp competition and low prices may depend upon the accuracy with which cost has been estimated; and this again will depend upon the knowledge of unit cost under the conditions that are to be met. These conditions vary greatly upon different pieces of work; and in different localities, and the estimator needs the accumulated knowledge that comes from habitual cost-keeping. It is important, therefore, that this branch of accounting should never be neglected on engineering work. Furthermore, it is important during the progress of any extensive work. The contractor or the manufacturer who has before him at the end of each week the unit cost of his work during that week can know whether it is being done with proper economy, and if it is not, he can ascertain the cause and apply the remedy at once, and thus prevent accumulated losses. Accurate accounts will often disclose defective management which may not be detected by personal observation during the progress of work.—*The Engineering Record, Sept. 20, 1902.*

Rapid Telegraphy.

IN the Rowland Rapid Telegraph System various modifications in the waves of an alternating current are adopted, cut-out positive and negative half-waves being employed for sending signals over the line. A single signal is, however, made to consist of a pair of cut-out half-waves which are not adjacent. This method leads to the system of "Wave-Groups," a very important feature of the invention. In practice, the Rowland system makes use of five groups of waves, with one extra half-wave between each group. Signals sent over the line are made by cutting out any two half-waves not adjacent from some of the different combinations formed. Professor Rowland found that he could employ about 208 alternations per second, and any group of waves will repeat itself four times each second. If there are four operators, to each of whom is assigned a special group of four waves, each can send four different signals each quarter of a second. Thus 960 different signals may be transmitted over the line in one direction in one minute. In reality the signals are sent over the line in succession, although the process is so rapid that they appear to be simultaneous. The system is also duplex, so that two different signals may be sent in opposite directions. Hence the total capacity for one wire is 1920 signals per minute. Professor Rowland has developed the system so that figures, letters, and other signs are automatically printed in such a manner that each operator, by writing on an ordinary Remington keyboard, prints messages at the other end of the line. Forty words per minute is an ordinary speed for a practised operator, so that altogether the eight operators mentioned above may transmit and print telegraph messages at the rate of 320 words per minute. The article from which these particulars are condensed commences a full description of the practical means by which the chief operations of the system are performed, and a further contribution is promised, in which will be described the method by which the transient signals are translated into a readable record and afterwards into printed characters.—*Electrical World and Engineer, Oct. 18, 1902.*

Street and Road Lighting.

A PAPER by Mr. S. Everett Doane on "Some Common Faults in Exterior Illumination" presents some opinions upon the question of outdoor lighting, which may be considered from two points of view—(1) the actual distribution of light to the object illuminated; (2) the value of the illuminant to the observer. The value of the first can be accurately expressed, and much has been said about it, yet the second is the practical end for which illumination is designed, and its value largely depends upon whether or not the source of light is in range of the observer's vision. Light delivered from a lamp near at hand is to be preferred to light delivered so far away that the rays reach the ground at a small angle. The greater the candle power and the more infrequent the lamps the smaller is the portion of the total light which actually reaches a roadway. Arc lamps located respectively 200 ft., 300 ft., and 400 ft. apart are evidently intended to illumine plane areas about 31,500, 70,000, and 125,000 sq. ft. in extent. A 20-ft. road crossing each of

these areas will receive about 12·7 per cent., 8·6 per cent., and 6·4 per cent. respectively of the light delivered to the ground. From this the author argues that lamps placed 200 ft. apart may consume one-half the energy and may be of one-half the efficiency, and still give equally efficient illumination and deliver their light from a more advantageous direction, than lamps placed 400 ft. apart. Arc lamps are at their best in densely settled districts, where the reflected light from buildings helps to economise distribution, and where the light from shopwindows assists to brighten the surroundings so that the brilliant arc-lamp is less blinding. Incandescent lamps, in the opinion of the writer, are much to be preferred for residential streets and for districts outside the more congested portion of a city or town. His opinion is that for a given expenditure of energy more light can actually be delivered to a highway by incandescent lamps than by arc lamps, and that it can be better distributed. —*Proc. Am. Inst. Electrical Engineers. Jan. 1902.*

The Bremer Arc Lamp.

IN this lamp the arc, which is maintained between a pair of inclined carbons saturated with certain mineral salts, has recently been subjected to careful photometric tests by two independent observers, M. Laporte in Paris, and Prof. Wedding in Charlottenburg. A full discussion of the two sets of experiments is given in *L'Éclairage Electrique* for Oct. 4. The results are not in very close agreement, though both bring out the superiority of the Bremer lamp over ordinary arc lamps. This is especially noticeable if one only considers the mean hemispherical candle-power for the lower hemisphere; since the construction of the Bremer lamp is such that, when used without a globe, practically all the light is thrown downwards. The distribution of light in this direction is also particularly good, being nearly uniform throughout an angle of 50 degs. on either side of the vertical. The consumption of power in a 400-watt lamp comes out at about 0·6 watt per spherical candle and 0·4 watt per hemispherical candle for the Bremer lamp with a globe, as against 1·1 and 0·65 for an ordinary lamp under similar conditions.—*Nature, Oct. 16, 1902.*

Encouraging Apprentices.

MESSRS. HANDYSIDE, makers of steel bridges, roofs, buildings, etc., of Derby, in order to encourage their apprentices, have arranged to pay half the fees, and purchase the necessary instruments and books for all their apprentices who attend evening classes at the Derby Technical College, in approved subjects, for a term of three years. Apprentices who pass the prescribed examinations will receive increased wages, and will be allowed to retain the instruments purchased for them. Another well-known firm which has adopted a similar system for the encouragement of apprentices is Palmer's Shipbuilding Company, of Jarrow.

The Engineer's Book-shelf

The Crompton Potentiometer. (Booklet published by Crompton & Co., Ltd., Chelmsford.)—The Crompton potentiometer is now a well-known instrument to students of modern text-books and to practical engineers, but for any who may be called upon to use it without being familiar with the principles on which it is constructed and on which its action depends, we would recommend a careful reading of this instructive little pamphlet supplied by the makers. It was Professor J. A. Fleming, F.R.S., who originally suggested the use of the potentiometer as a standard instrument for electrical measurements in direct current supply systems, but to Colonel Crompton is due the credit of having first developed the instrument, and introduced it into engineering practice. From the time of its introduction it has steadily gained favour, and is now in extensive use not only in laboratories, but in supply stations where direct current is generated.

The theory of the instrument is that a potential difference may be measured by connecting it up to the ends of a known resistance, and by balancing on a bridge-wire the potential difference between two points on this resistance, which include between them a known small fraction of the total resistance, against the known electromotive force of a standard element, such as a Clark cell. The high resistance is provided in what is called the volt-box, which may be made in various sizes depending upon the maximum voltage to be measured.

In Fig. 1 is shown a volt-box, having eleven terminals along its remote side. The resistance between any two consecutive terminals is 10,000 ohms, and between the two end terminals 1,500 volts can be carried. The terminals nearer the front of the box are those of known small resistances tapped off from the resistances in the back row, and thus they have between them small potential differences which may be balanced against a Clark cell on the bridge wire.

Fig. 2 shows the potentiometer itself. The

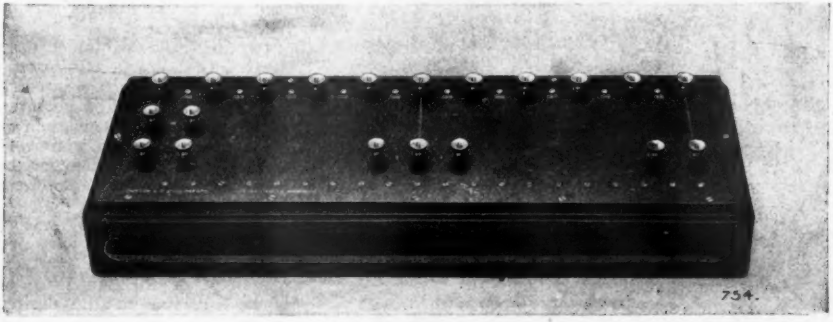


FIG. 1.—THE CROMPTON POTENTIOMETER.

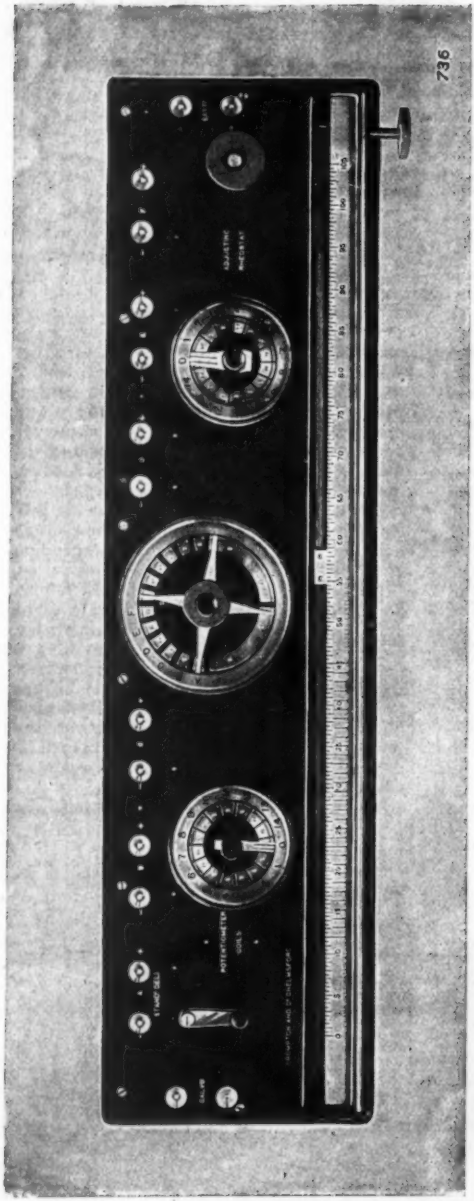


FIG. 2.—THE CROMPTON POTENTIOMETER.

calibrated wire is arranged in 14 coils, called potentiometer coils, and a straight section stretched along the graduated strip in front of the box. The resistance of the several coils is the same as that of the straight section, and the number of coils in series with the bridge wire can be altered at will by the switch on the left-hand dial in the figure, where the contacts are seen numbered 0 to 14. Of the six sets of terminals along the back edge of the board, one is kept for the standard cell, while the others may be connected up to different potential differences; and any particular potential difference may be selected for measurement on the bridge by turning the double pole switch on the middle dial to the proper contacts. The dial and disc on the right belong to resistance coils and a rheostat respectively, by means of which the current from the battery can be adjusted so as to give a balance for a Clark cell at a known temperature at the bridge-reading which expresses the correct E.M.F. at that temperature, after which the instrument gives correct readings in *volts*, instead of in terms of E.M.F. of Clark cell. The galvanometer terminals and switch are seen on the left, the battery terminals on the right. The latest improvement in the instrument is the providing of a switch by means of which each of the potentiometer coils may be separately compared with the scale wire, so that their equality to it and to one another may be readily verified.

In this little pamphlet from Messrs. Crompton & Co., useful information is given regarding the employment of the potentiometer for measurements such as are required in station practice—as, *e.g.*, the measurement of the power absorbed by a motor, or of the efficiency of a pair of similar machines. Diagrams of the connections are given and are accompanied by a short explanation of the steps to be taken to arrive at the desired result.

Designing Ironwork. Part III. Cisterns and Tanks.—By Henry Adams, M.I.C.E., etc. London: 60, Queen Victoria Street, E.C. 2*s.* 0*d.*

This is a most useful continuation of the series in course of publication by the author, especially as the subject to which it is devoted is one that seems to be left severely alone in text-books relating to iron and steel construction. The value of the pamphlet is considerably enhanced by two folding plates, containing 78 separate drawings of details.

The Mechanical World Pocket Diary and Year-Book for 1903. Manchester: Emmott & Co., Ltd. 6*d.*

As a pocket diary this book is a distinct failure, as only about 50 pages out of some 360 pages are devoted to the purpose. As a well-arranged, carefully selected, and admirably printed collection of useful engineering notes, rules, tables and data, it is a great success, and is well worth double the small price asked.

The Sea Coast.—By W. H. Wheeler, M.Inst.C.E. (London: Longmans, Green & Co., 1902.)

Very little has been written on sea-coast protection except, perhaps, in articles for technical journals and papers for engineering societies. Mr. Wheeler's book, therefore, comes as a welcome addition to the library of the civil engineer. The treatise before us deals first with the phenomena necessitating the execution of defensive works; it then discusses the construction of such works and, finally, presents a comprehensive description of the sea coasts of England and Wales and the measures adopted for their protection. The author makes it clear at the beginning that no special method of protection can be recommended as a panacea, and his efforts are accordingly confined to the giving of such information as may be helpful to those concerned in the preservation of land on the seaboard. All land so situated is perpetually being worn by the action of waves, as well as by rain and frost. In either event the materials carried down to the shore are added to the beach, so tending to afford some measure of natural protection, the value of which depends altogether on the characteristics of the material. Thus chalk cliffs are easily disintegrated, and the resulting *débris* is of no protective value, and there are very few places where cliff destruction yields compensation worthy of serious notice Hence, protective works are necessary wherever towns exist near the sea shore. On other parts of the coast, where land is merely used for agriculture, the durability of protection depends largely upon financial considerations; and it is pointed out that the cost of preserving land would frequently be too heavy to make its adoption practicable or advisable.

After explaining the laws governing the action of waves and the effects produced by them on the shore, the author discusses the movement of beach material along the shores of a tidal coast. This movement, known as "littoral drift," has a most important bearing on the work of the marine engineer. In some places there exist large accumulations of material due to conditions long since terminated; but, as a rule, it may be said that the shingle drifting along the coast is strictly limited in quantity. Mr. Wheeler points out that at the present time the wear and tear of the sea cliffs does little more than supply the waste which is always going on, and that as there is no other source of supply the practice of removing beach material for commercial use is strongly to be deprecated.

Coming to the design of sea walls, the author shows how difficult it is to comply with the theoretical requirements of such structures. Vertical walls result in the projection of water in an upward direction, so concentrating action upon places where the consequences are most prejudicial, for the water, falling at the back, or upon the beach, tends to cut out material and threaten the durability or stability of the masonry. Concave walls have also some disadvantages, for a large proportion of the materials are placed where little horizontal force is to be resisted; while the upper part of the curve offers considerable opposition to the upward stroke of the water. A sea wall having a projecting curb or nosing is still more objectionable for the same reason. Several instances are cited where projections of the kind have had to be removed. In some places the masonry has been loosened, in others coping stones have been lifted, and at Ramsgate it is said that a nosing set up action causing disintegration of the chalk and denudation of the beach to such an extent as to threaten the stability of the wall for a considerable length. Mr. Wheeler objects to walls with a stepped face, because a broken surface is offered to the water, and the successive courses of masonry are not held down by the upper courses as in the case of a vertical wall. Sloping walls suffer even more from the last-mentioned disadvantage, and as they must extend further seaward, wave effects are felt for a longer time during the flow and ebb of the tide. The section considered by the author to be best is one in which the face presents an elliptical curve, merging at the bottom into a slope natural to a beach composed of shingle or sand. In the latter case the toe may be carried farther out by an apron, protected at the end by sheet piling. In either case the object is to lead the water back by easy and correctly designed curves, so that the cutting out of material may be obviated. The mean width of section recommended is not less than one-half the height above the beach level, but this proportion may have to be increased if pressure from behind has to be resisted. In height a wall will vary according to circumstances, but it should be such that waves shall never be able to break over the top of the wall.

In Chapter VI. there is much useful informa-

tion as to the object and design of groynes. While not acting as protections to a coast, groynes tend to preserve the land by assisting in the collection of shingle. Low groynes across sandy beaches help to fill up the hollows, and to convert soft surfaces into firm sands. Mr. Wheeler says that although groynes are most useful on shingly shores, their value must not be over-estimated. High groynes increase the destructive influence of the waves as the water is projected upwards, and in falling it erodes and cuts out the beach. On the question of spacing, he says that experience of local conditions is the best guide, and that consideration of what has taken place at various towns shows how inadvisable it is to multiply the groynes more than is absolutely necessary. Cases are mentioned where single groynes have led to the collection of beach material for considerable distances, and to such depths that old groynes have been completely covered In commenting upon the Case system of groyning, the author generally approves of the principles adopted by Mr. Case, but he criticises the practice of stopping the groynes at mean high-water line, because this permits water to run round their ends, and so to scour out the beach.

We now come to the second part of the volume, and while we cannot attempt to refer in detail to the many interesting facts presented, some brief notices of a few will serve to give the reader an idea of the great interest and value attaching to the records in this portion of Mr. Wheeler's work. As an instance of the alterations that may follow the construction of harbour works, the case of Weymouth is cited. It appears that since the construction of the Portland breakwater, shingle has left the beach protecting the northern part of Weymouth and drifted away towards the south in superabundant quantities. The unwisdom of removing beach material for building purposes is illustrated by the case of Swanage, where serious encroachment has thereby been experienced, destroying buildings on the shore, and threatening the road which runs along the sea front for nearly a mile. Considerable attention is paid to the elaborate precautions taken at Brighton. Mr. Wheeler says the system of groyning there is the most expensive along the south coast, while the cost of maintenance amounts to fully £2,500 per annum. Yet in spite of this the groynes are unsatisfactory, affording inadequate protection, and interfering with the enjoyment of the beach by visitors. Seaford has suffered from the construction of the high and unsightly groynes at Brighton, but the subsequent construction of a sea wall and groynes have helped materially in the re-accumulation of shingle. Two different systems of protection are exemplified by Hythe and Seabrooke. A concrete wall was built some years ago at Hythe, about a mile long and fifteen feet high, and near the east end of the wall a single groyne was built of timber and concrete, which has accumulated a shingle beach almost as high as the top of the wall, and extending nearly to the west end of the wall, covering all the old groynes. At Seabrooke there is a number of high groynes, each one collecting shingle on the windward side, and doing nothing to help the leeward side. Consequently the shore presents a serrated appearance, which is not only unsightly, but is a direct assistance to the destructive action of the waves. Moreover, so little beach material has been collected at the east end of the shore, that in 1898 the roadway was cut out, and the sea wall was partially destroyed. Below the Humber, one of the rare examples occurs where the shore line is extending seawards, and a considerable area of land in Lincolnshire has been reclaimed within the last fifty years. On the Norfolk coast, Sheringham has suffered much from the sea, largely by the influence of a high groyne built by a local landowner in 1895. The result was that several houses were destroyed, together with much land. Mr. Wheeler says that one landowner has lost thirty acres, and that in 1897 two acres were swept away by the sea during a single storm. Cromer, once an inland hamlet, is now obliged to fight the sea; and the once important town of Dunwich has long since been swallowed up, its last remaining church now standing perilously on the edge of the cliff. The history of Landguard Point affords an example of the care that ought to be displayed in tampering with the natural conditions of the sea coast. More than a century ago a rocky ledge acted as a groyne, checking the drift of shingle across Harwich Harbour. The greater part of this ledge was removed for the manufacture of cement, and about 1800 two Martello towers and a battery were lost, and the shingle extended beyond Landguard Fort until the navigable channel was reduced in depth from seven fathoms to little more than one fathom. Then a groyne was constructed to remedy this state of things, but the beach inside the harbour became so denuded that the safety of the fort was threatened. To remedy this state of things, part of the groyne was taken down to let some of the shingle pass through, with the result that shallows were caused at the mouth of Felixstowe Dock, and other works had to be taken in hand to rectify this additional trouble. On the other side of Harwich Harbour, also, the removal of stone by cement-makers caused the disappearance of 250 feet of the cliff, and the present breakwater had to be built by Government, at much cost. These are significant examples of unwise and thoughtless meddling.

In addition to describing the sea coasts of our own land, Mr. Wheeler gives some very useful particulars of the practice adopted in France, Belgium, and Holland. His work possesses an advantage likely to be appreciated by the general reader, that while discussing the whole subject of sea-coast protection amply and intelligently, it is not cumbered unnecessarily with the minutiæ of timber and masonry construction. Landowners and members of Local Government bodies who may be interested in the preservation of land will be able to make themselves acquainted with the general principles involved in any scheme intended to keep the enemy at bay, and to learn what has been successfully accomplished in circumstances resembling their own, while engineers will find the treatise a most invaluable storehouse of practical information.

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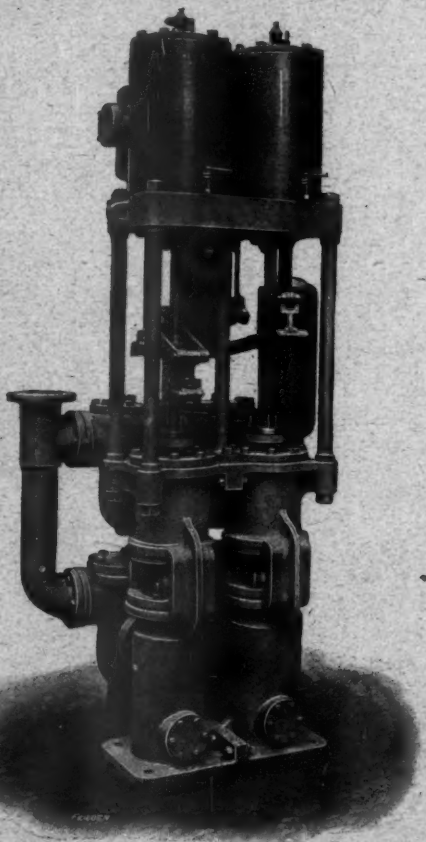

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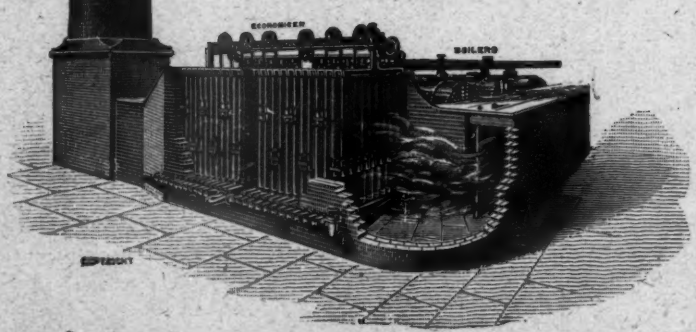

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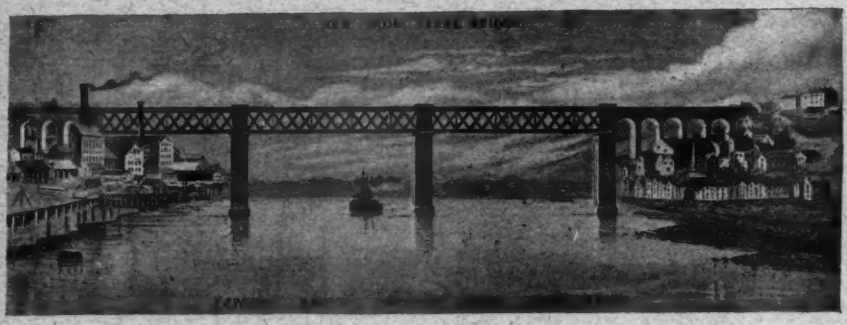

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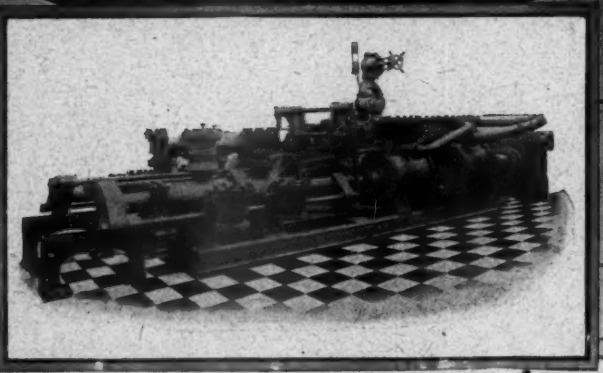

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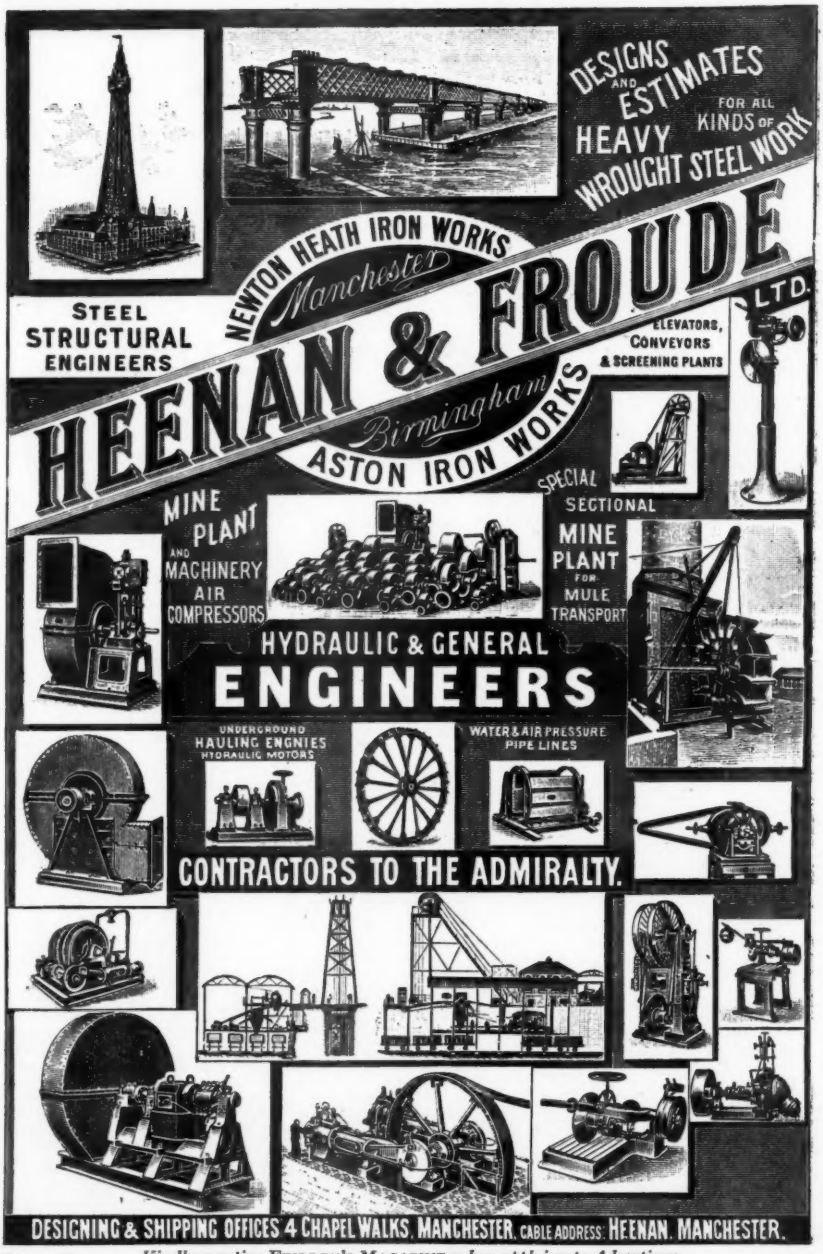
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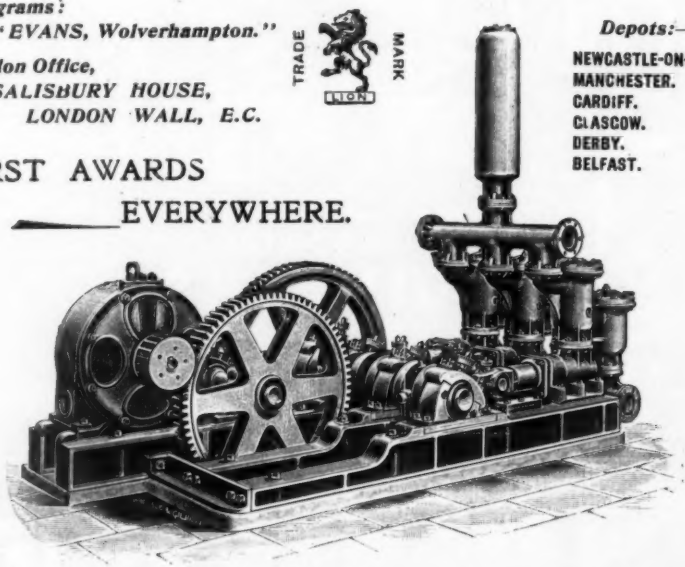

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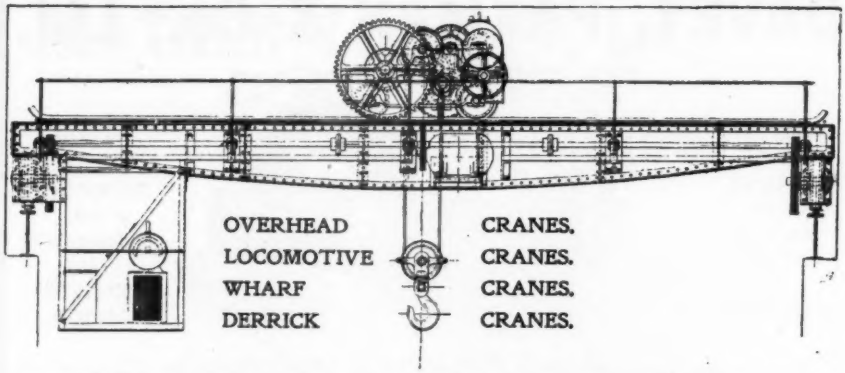

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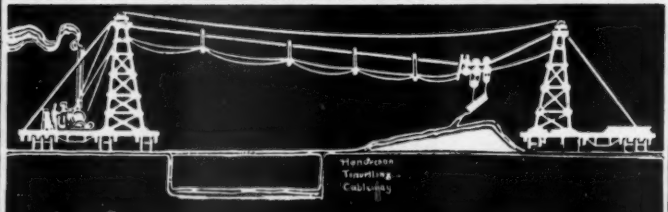

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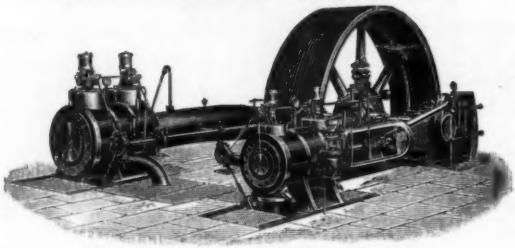

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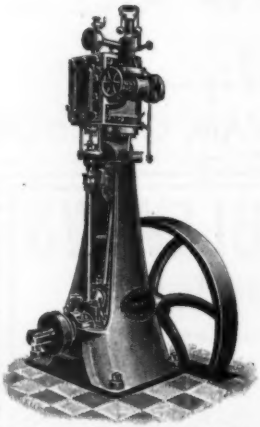

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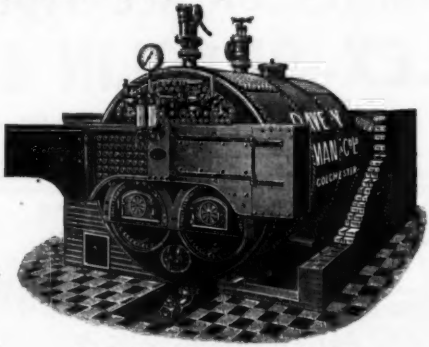

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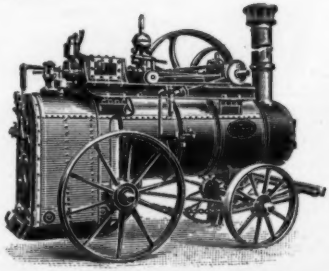

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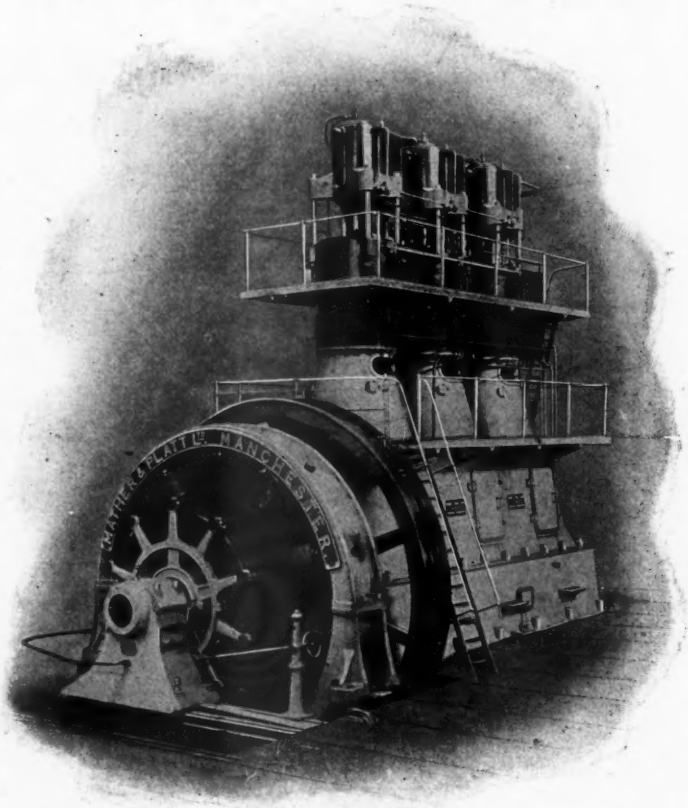

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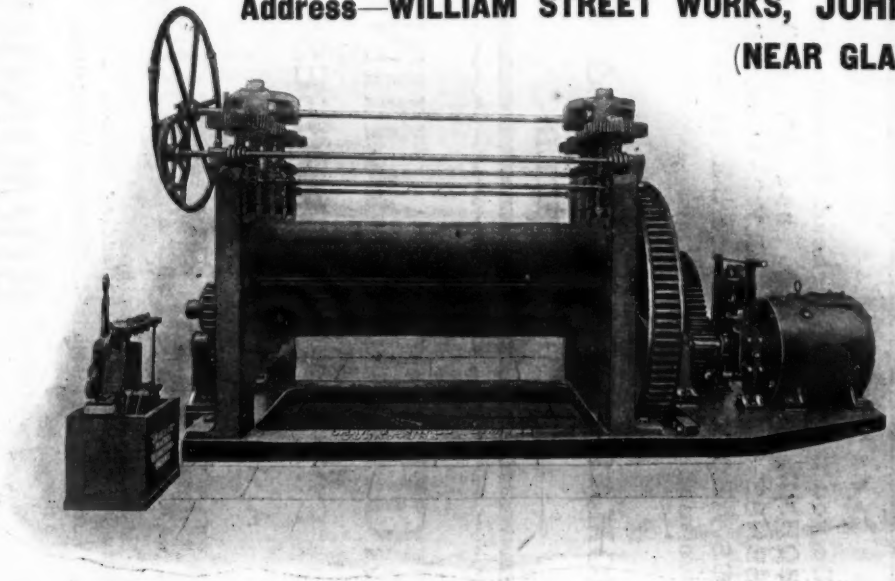

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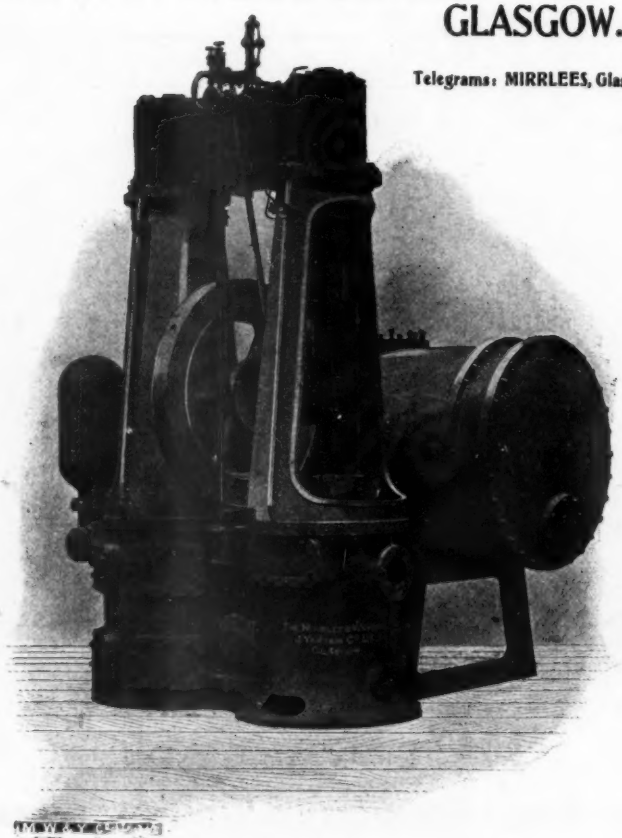

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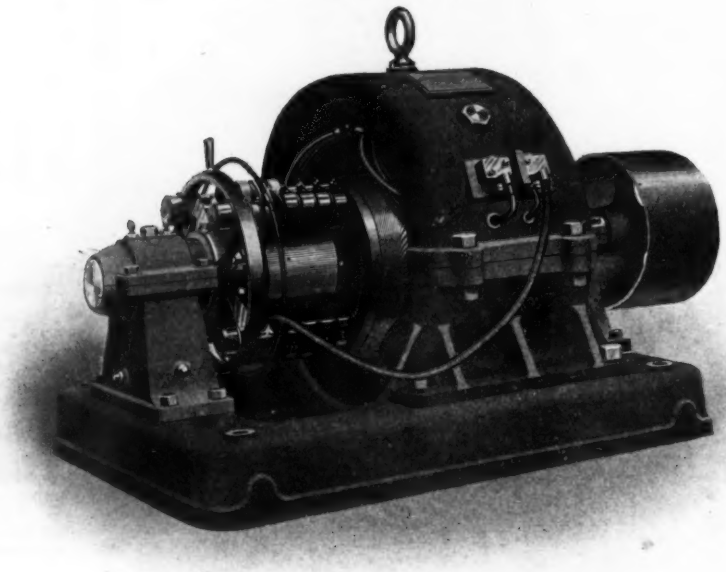

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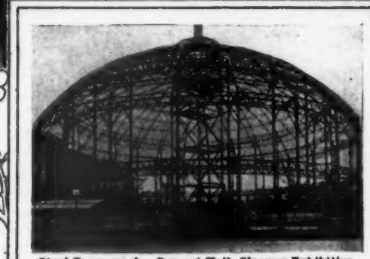

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DIFFERENTIAL CALCULUS FOR BEGINNERS: by Alfred Lodge, M.A., with an Introduction by Sir Oliver J. Lodge, D.Sc., F.R.S., LL.D. London: Messrs. George Bell & Sons. Cambridge: Messrs. Deighton, Bell & Co.

MECHANICAL ENGINEERS' POCKET-BOOK FOR 1903. Edited by William H. Fowler. Manchester: Scientific Publishing Co. Price 1*s.* 6*d.* net and 2*s.* 6*d.* net.

GALVANIC BATTERIES: Their Theory, Construction and Use, comprising Primary, Single and Double Fluid Cells, Secondary and Gas Batteries: by S. R. Bottone. London: Messrs. Whittaker & Co., Paternoster Square. New York: 66, Fifth Avenue. 1902. Price 5*s.*

THE "PRACTICAL ENGINEER" ELECTRICAL POCKET BOOK FOR 1903. Manchester: The Technical Publishing Co., Ltd. Price 1*s.* net and 1*s.* 6*d.* net.

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METALLIC PACKING. A descriptive pamphlet issued by The United States Metallic Packing Co., Ltd., of Soho Works, Thornton Road, Bradford, of their automatic self-adjusting metallic packing for locomotive, marine, and stationary engines, with list of British users.

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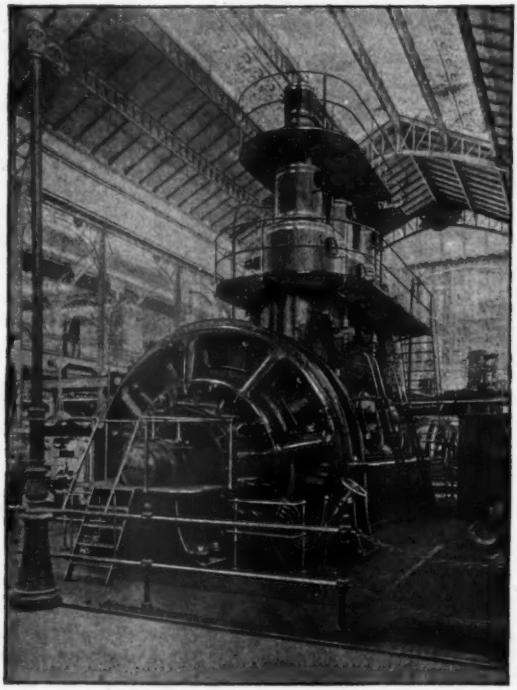

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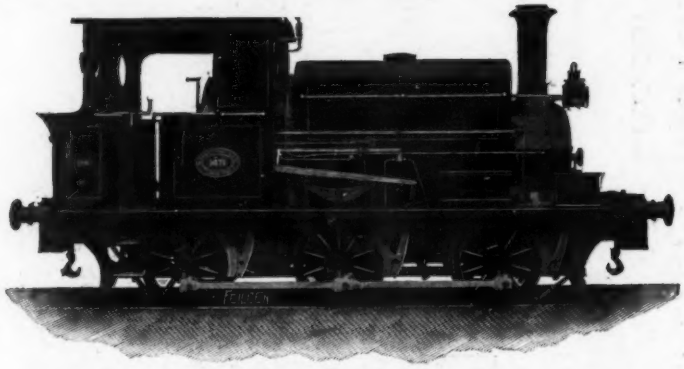

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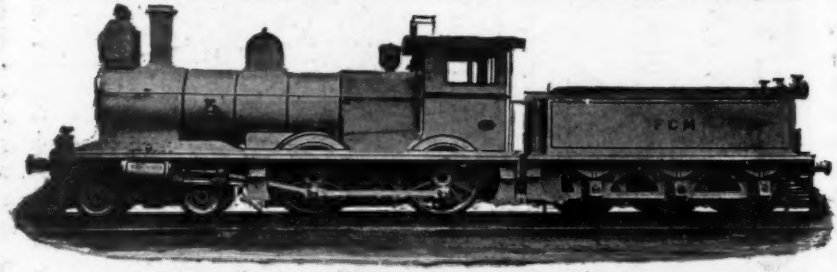

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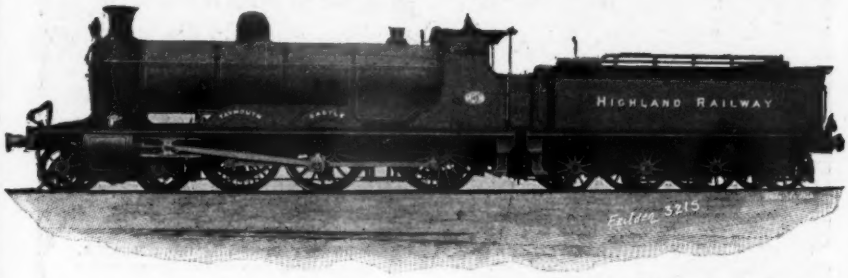

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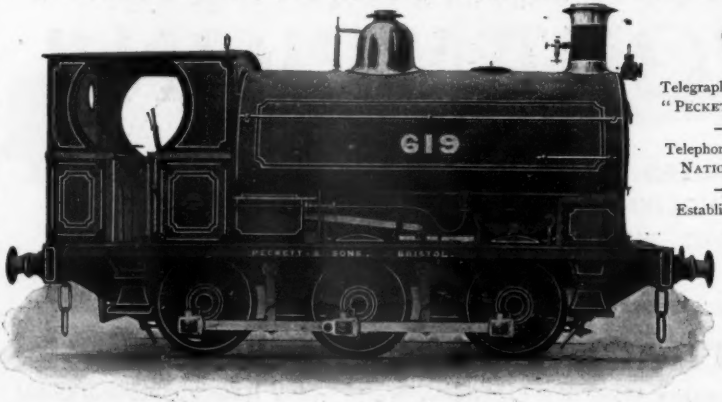

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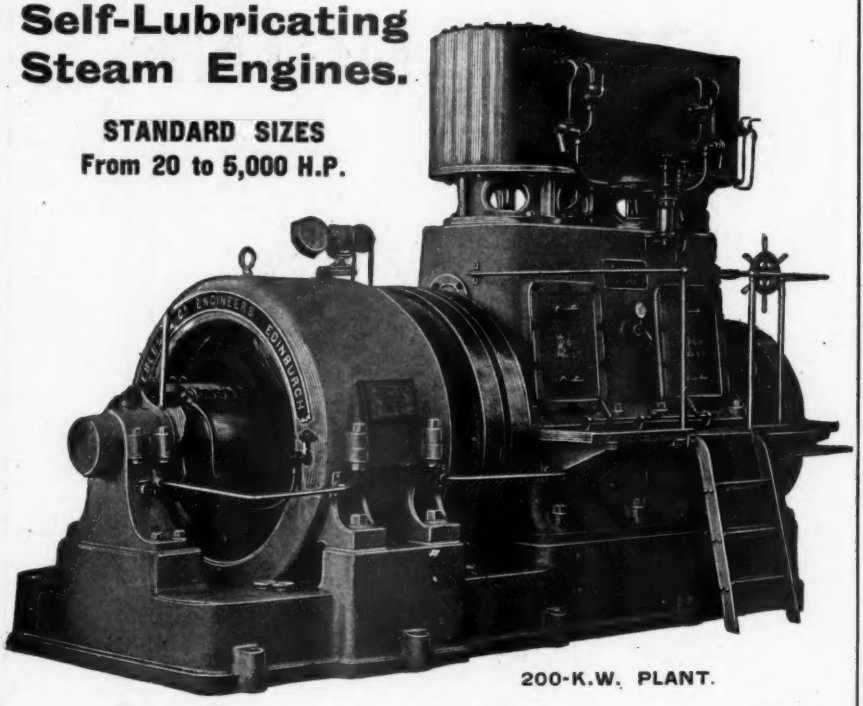

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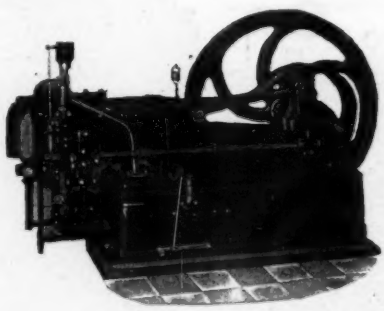

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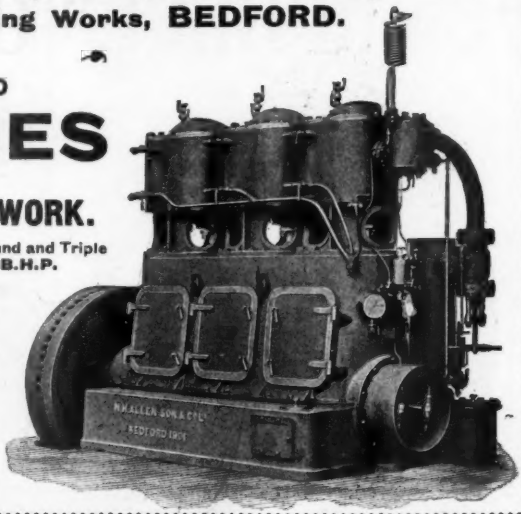

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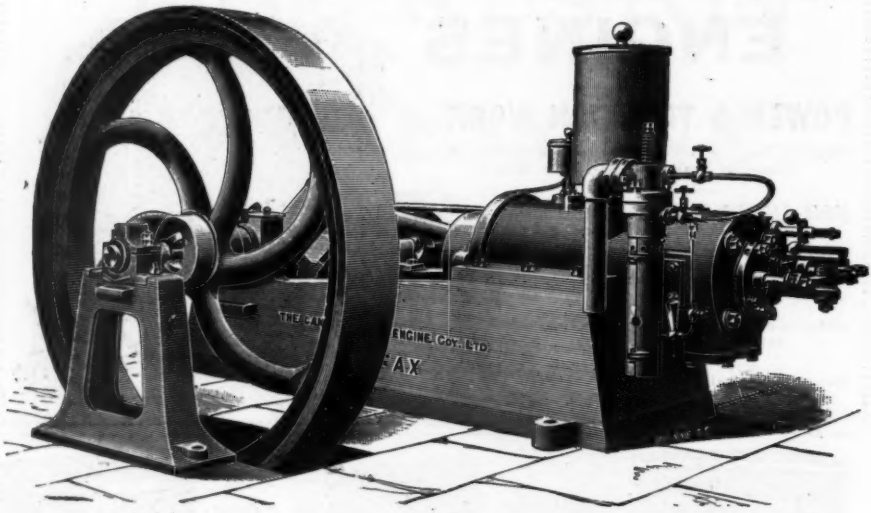

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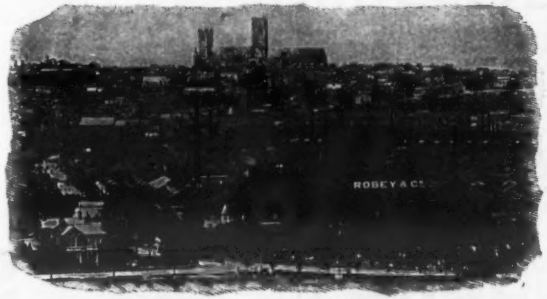

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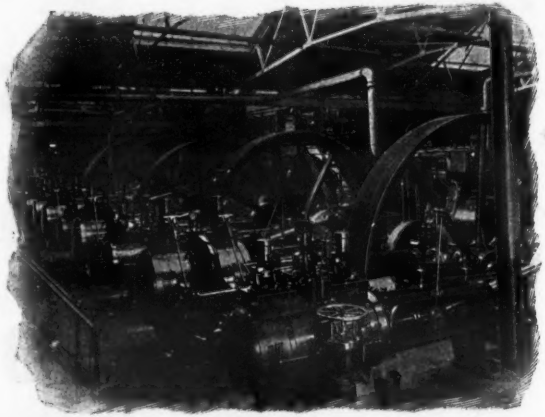

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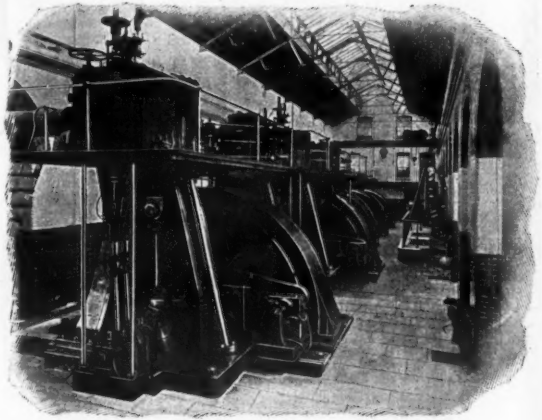

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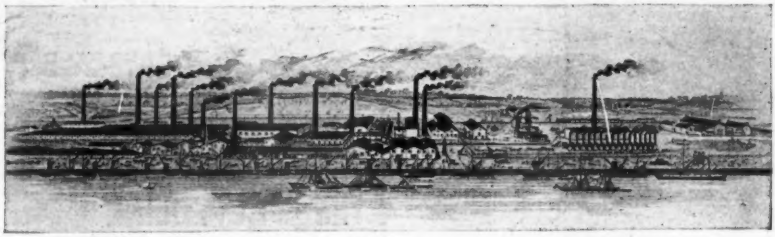

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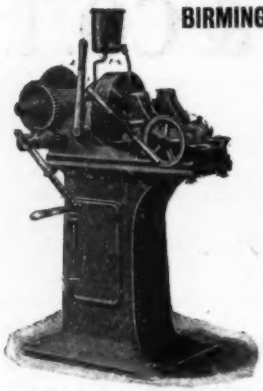

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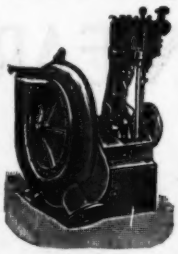

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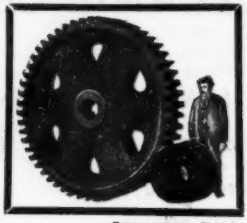

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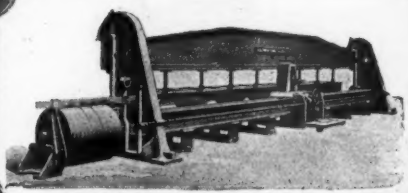

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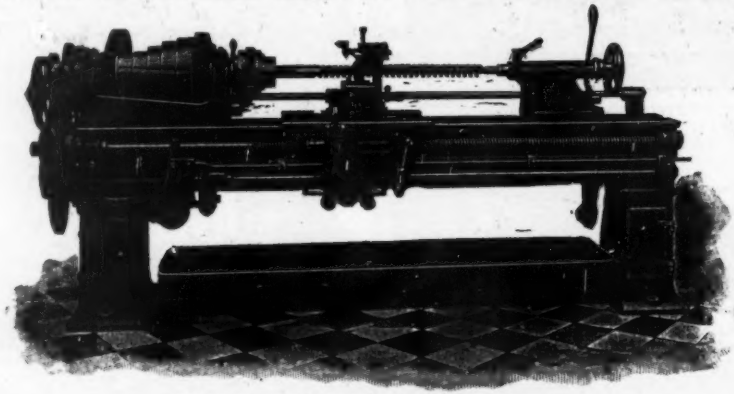

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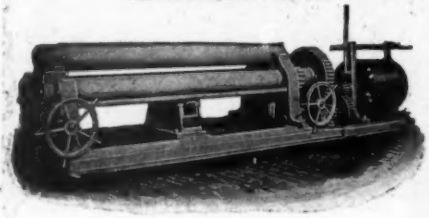

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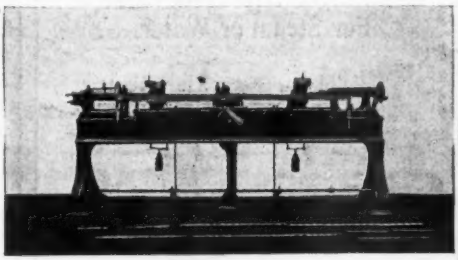

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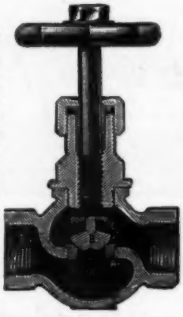

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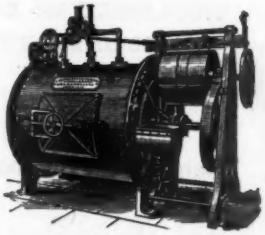

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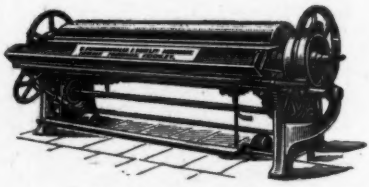

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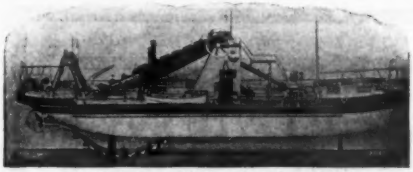

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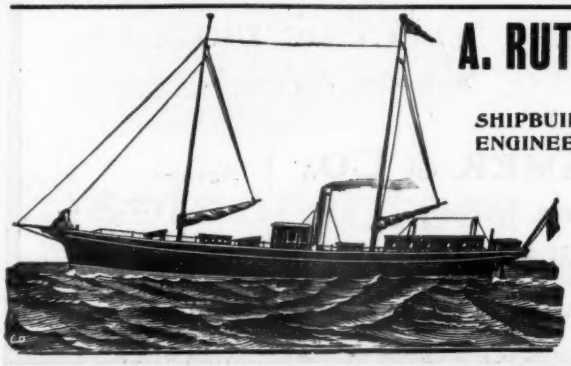

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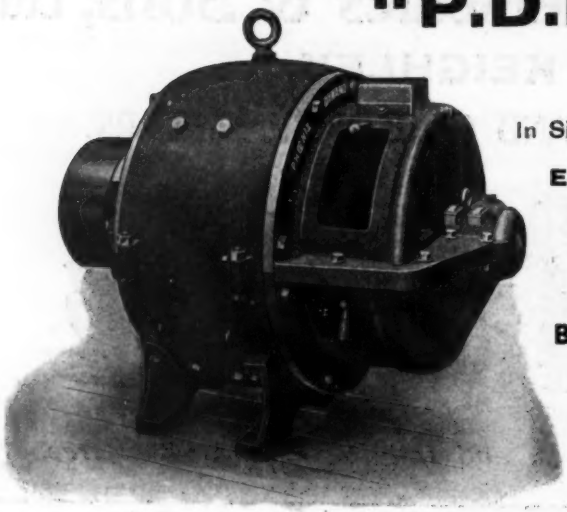

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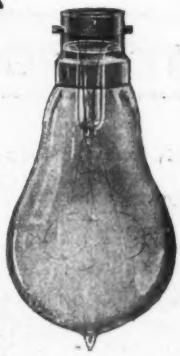

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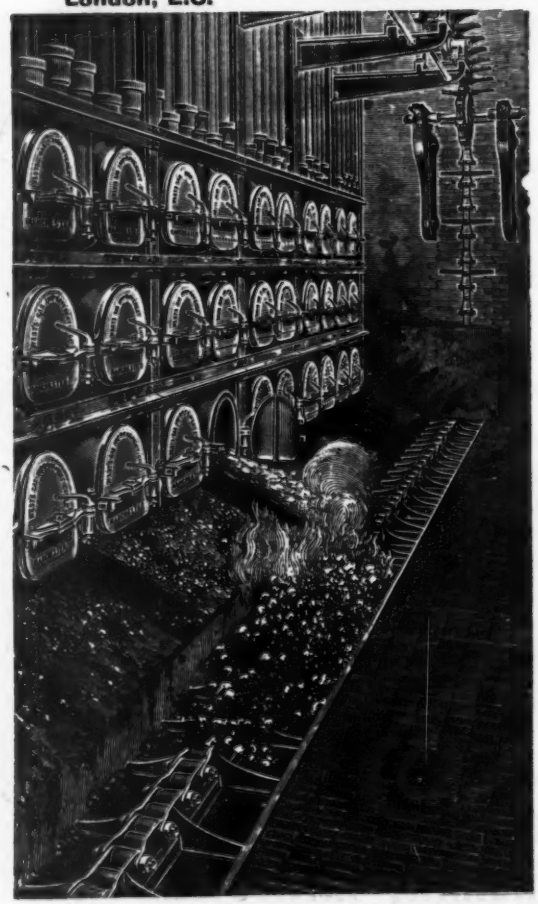

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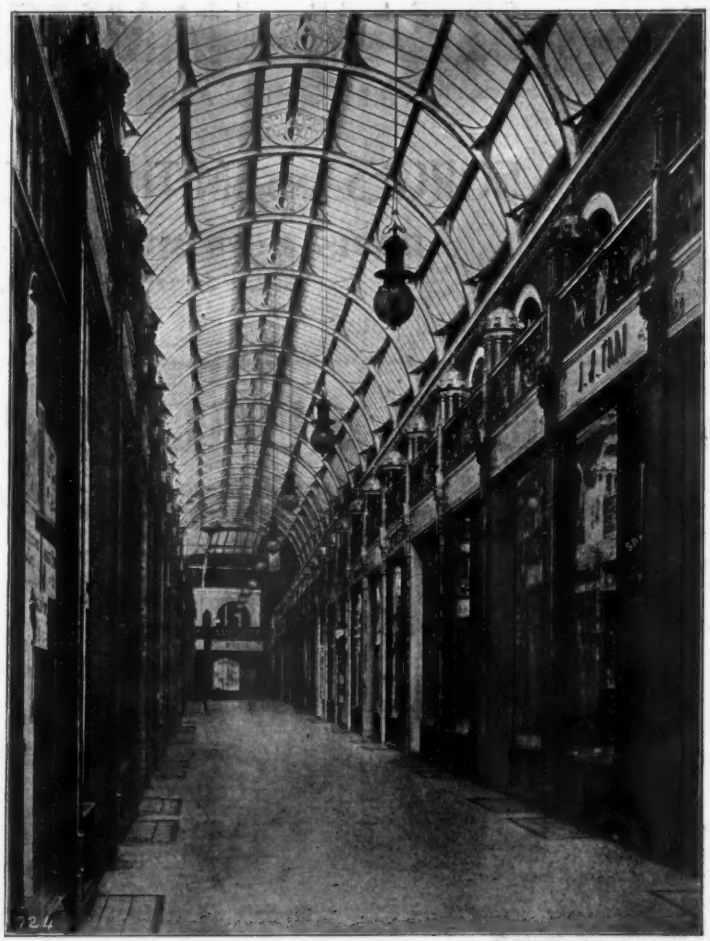

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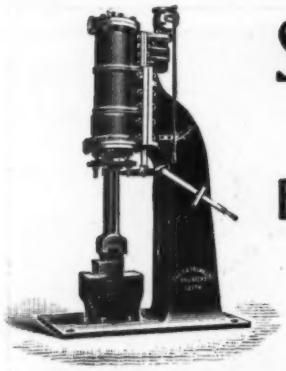

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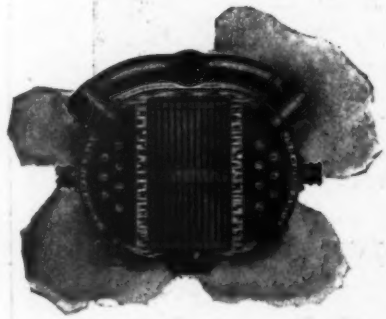

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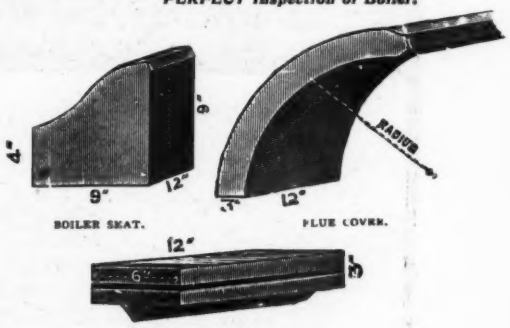

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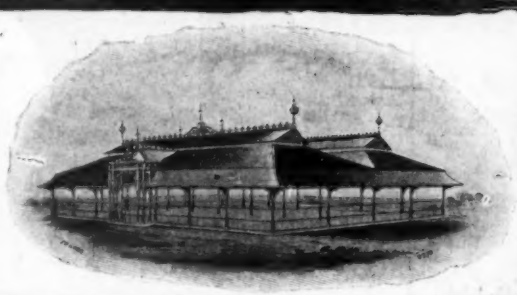

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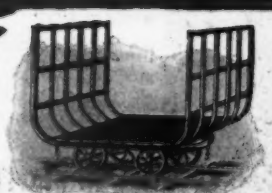

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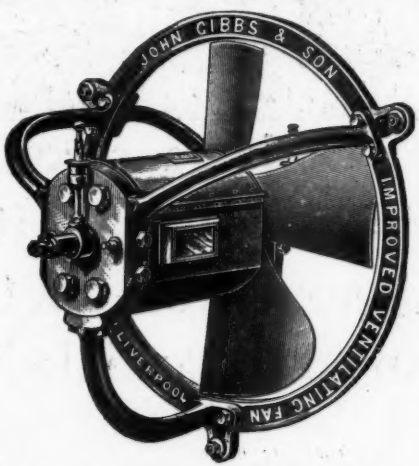

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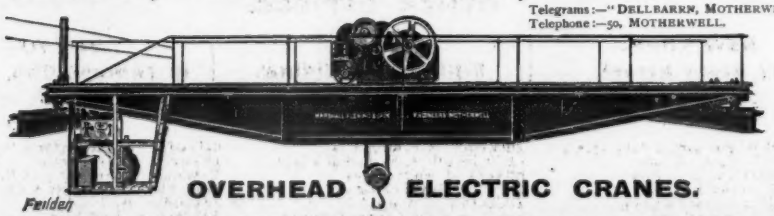

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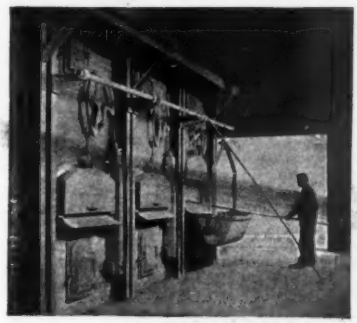

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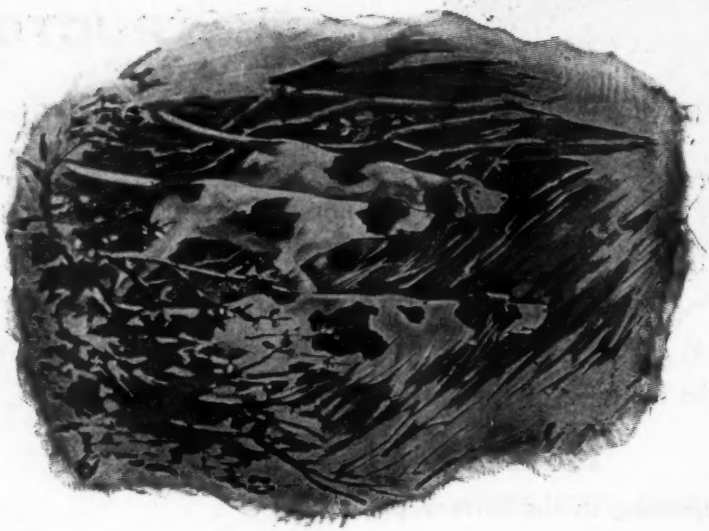

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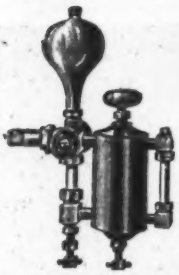

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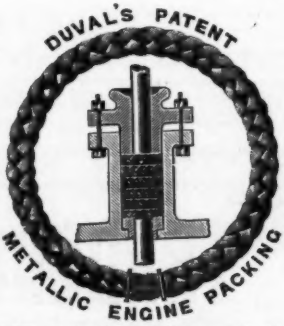

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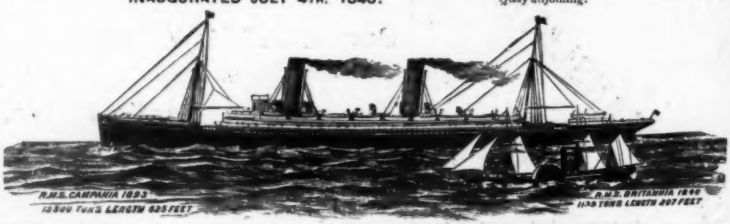

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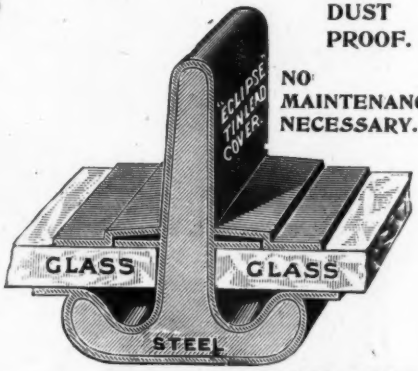

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The Works of Messrs. W. P. Butterfield, Shipley, Yorks.

FROM time to time articles, under the heading of "How Great Britain is Meeting Foreign Competition," have appeared in FEILDEN'S MAGAZINE, the purport of which has been to describe the works and methods of manufacture adopted by the more up-to-date firms of this country. Although in magnitude the works of Mr. W. P. Butterfield are not to be compared with those described under the above-mentioned heading, yet in the thoroughness of the equipment and the refinement of manufacturing methods, this enterprising firm deserves some commendation. The present works are the most recent stage of a business development which had its origin twenty years ago in a small cellar wherein Mr. Butterfield commenced the manufacture of gas and oil-engine tanks, of which, to-day, he claims to be the largest maker in the world, the output consisting of 300 standard-sized tanks per week, and even more of smaller dimensions.

The first portion of the present works, which cover over half-an-acre of ground, was opened four years ago, since which date three other bays have been added, at the rate of one a year. A reserve of ground, three acres in extent, has been acquired for future additions.

The equipment contained therein is of the most up-to-date description, and numbers over fifty machines for shearing, punching, flanging, etc., all of which are belt-driven, and have the machine gear guarded. A mechanic's shop for die and tool-making is in process of construction, to contain milling machines and a large-size turning lathe.

Surrounding the shops are between five and six hundred bins, arranged for holding iron and sheet metal cut to standard dimensions, the process of manufacture, which is arranged on strictly standardised principles, commencing by their removal to neighbouring bending rolls, thence to be put through the punching, riveting, and flanging processes.

The disposition of the machines is such that the work is in a forward direction always, and no time is wasted by traversing ground over which it has once passed.

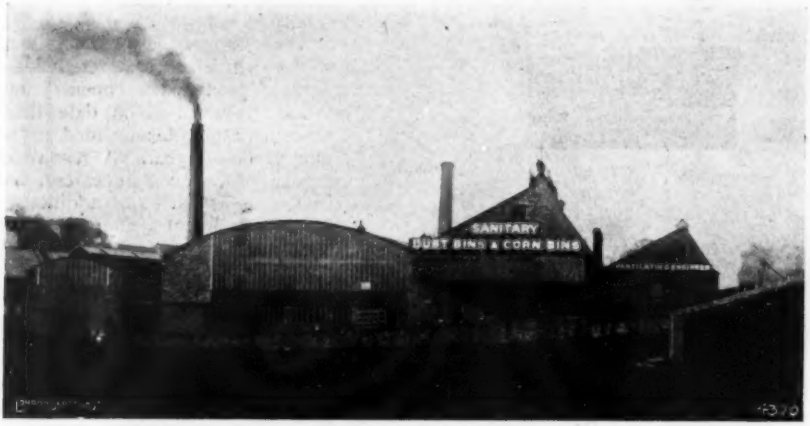
The galvanising department is over 90 ft. in length, and is fitted with an overhead crane of 30 ft. span for handling with facility the tanks, etc. This room contains six pickling vats and a large

galvanising bath, having a total capacity of 25 tons.

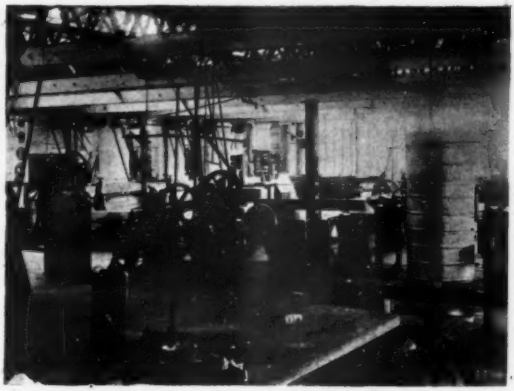
The basement of the works constitutes the finished stores, where over 1,000 cylinders, in addition to copper boilers, dustbins, corn bins, and cattle troughs, all of which utensils are made here, are kept in stock.

Mr. Butterfield's interest does not end at securing the highest mechanical efficiency, but extends to the welfare of his staff, for whom he has provided a dining-room fitted with lockers, etc., and a billiard room. A series of evening classes in technical subjects, held at the works, has also been arranged, a feature to which other employers would do well to give some consideration.

The accompanying illustrations show the exterior of the works, three views in the machine shops: the smiths' shop, galvanising department, and finished stock room.



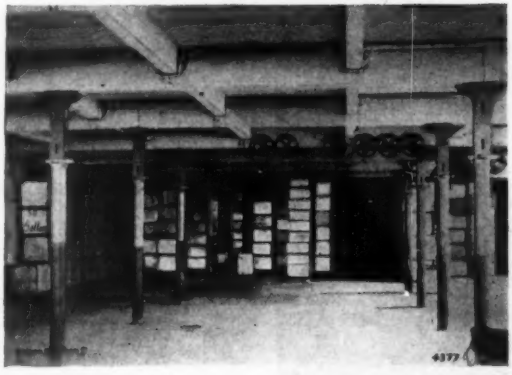
EXTERIOR OF MESSRS. BUTTERFIELD'S WORKS.



VIEWS IN THE PUNCHING, SHEARING, AND RIVETING DEPARTMENTS.

THE SMITHS' SHOP.

THE GALVANISING DEPARTMENT



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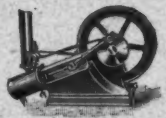

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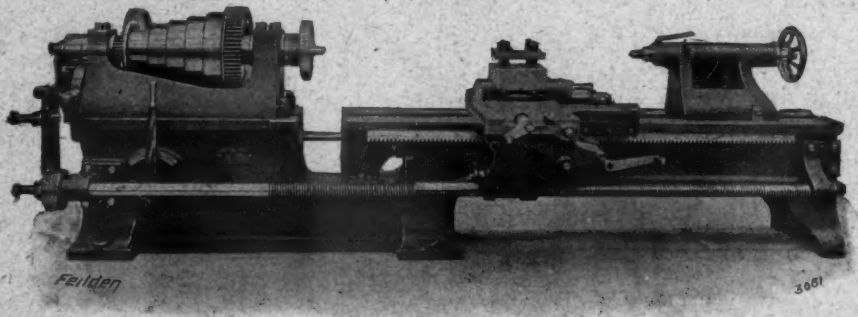

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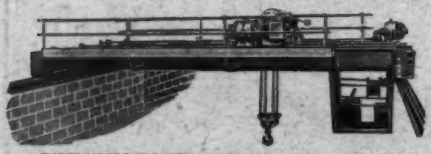

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